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Fox et al.

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(54) **SELF-ALIGNING PIPE GRIPPING ASSEMBLY AND METHOD OF MAKING AND USING THE SAME**

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(22) Filed: **May 31, 2013**

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B25J 15/00 (2006.01)
E21B 19/06 (2006.01)
E21B 19/16 (2006.01)

(52) **U.S. Cl.**

CPC ***B25J 15/0028*** (2013.01); ***E21B 19/06*** (2013.01); ***E21B 19/16*** (2013.01)

(58) **Field of Classification Search**

CPC B25J 15/0028; E21B 19/06; E21B 19/16; E21B 19/07; E21B 19/10
USPC 294/192, 207, 102.1; 92/109, 172, 178
See application file for complete search history.

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Primary Examiner — Gabriela Puig
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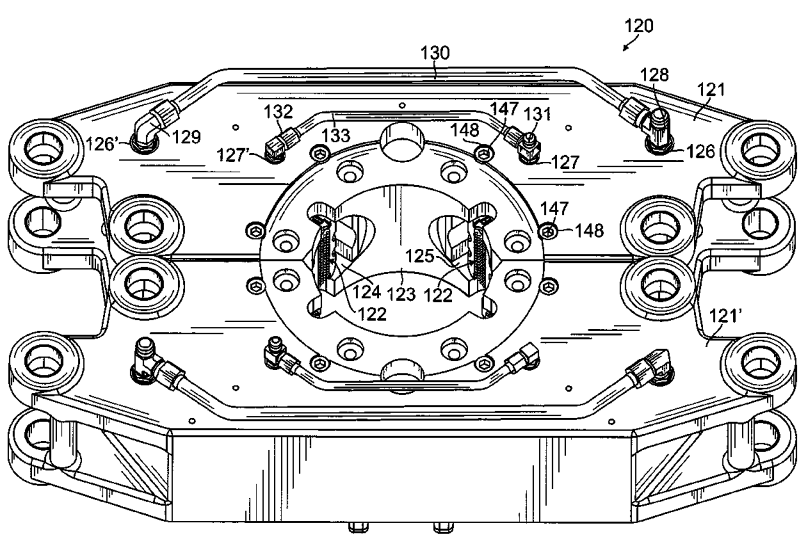
(57) **ABSTRACT**

A self-aligning piston is configured to selectively engage and disengage a pipe segment to permit a top drive output shaft to be coupled to the pipe segment. In one embodiment, the self-aligning piston includes a piston body configured to rotate between a first position and a second position, at least one resilient, energy-storing member coupled to the piston body, a roller assembly coupled to the piston body, and a cam disposed between the at least one resilient, energy-storing member and the roller assembly. The resilient, energy-storing member is configured to bias the piston body into the first position by rotating the roller assembly along the cam.

20 Claims, 18 Drawing Sheets



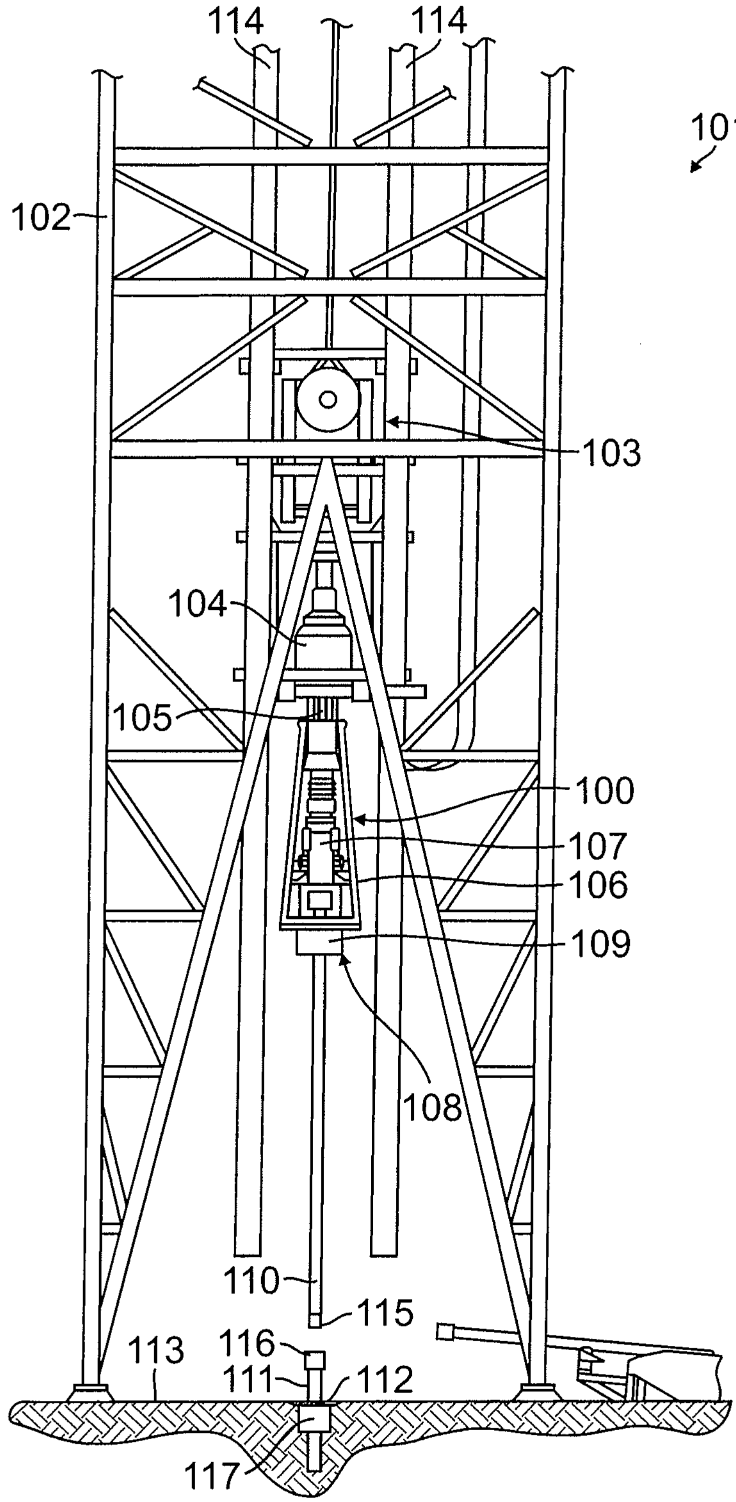

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FIG. 1

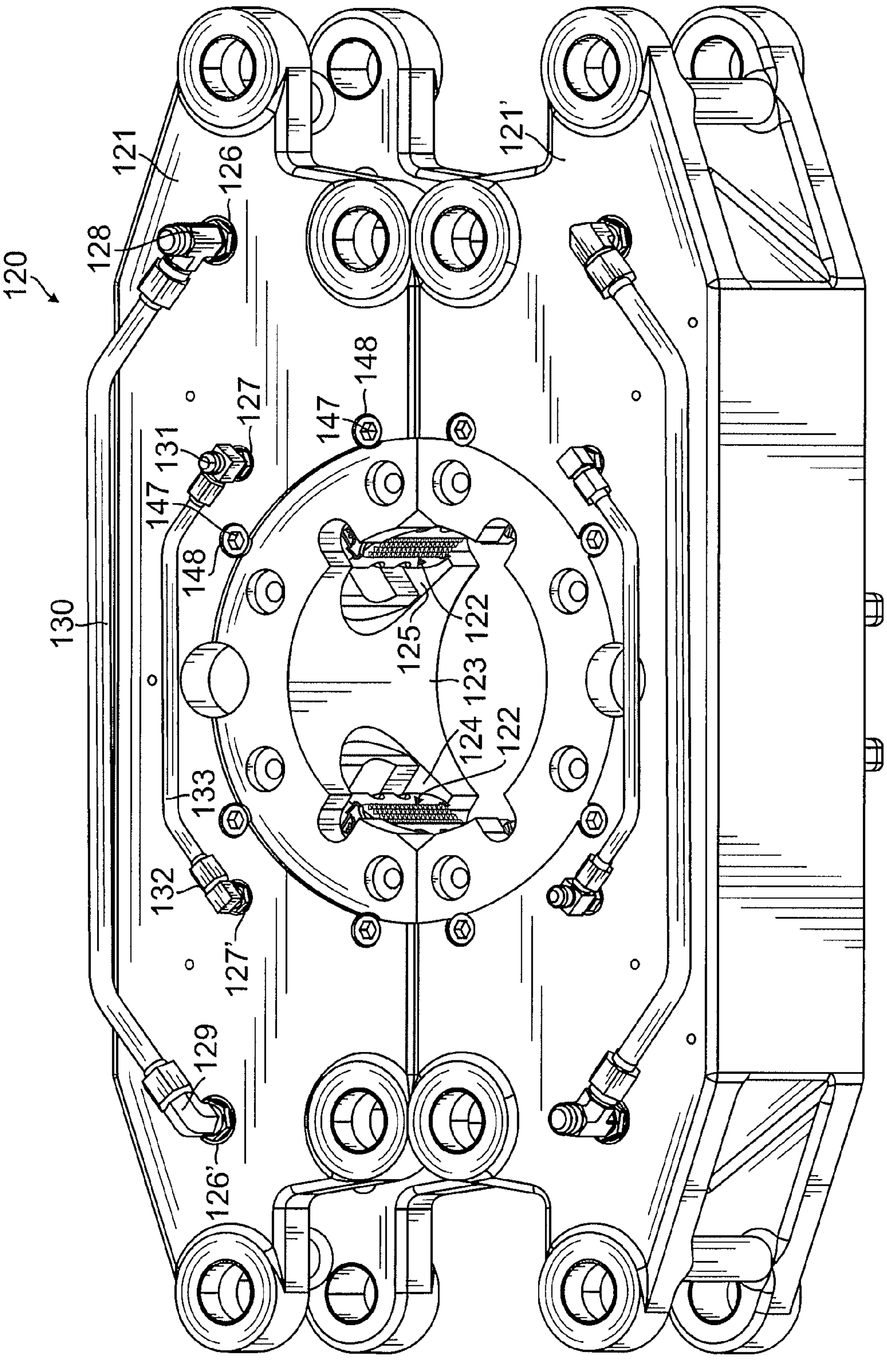
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FIG. 2A

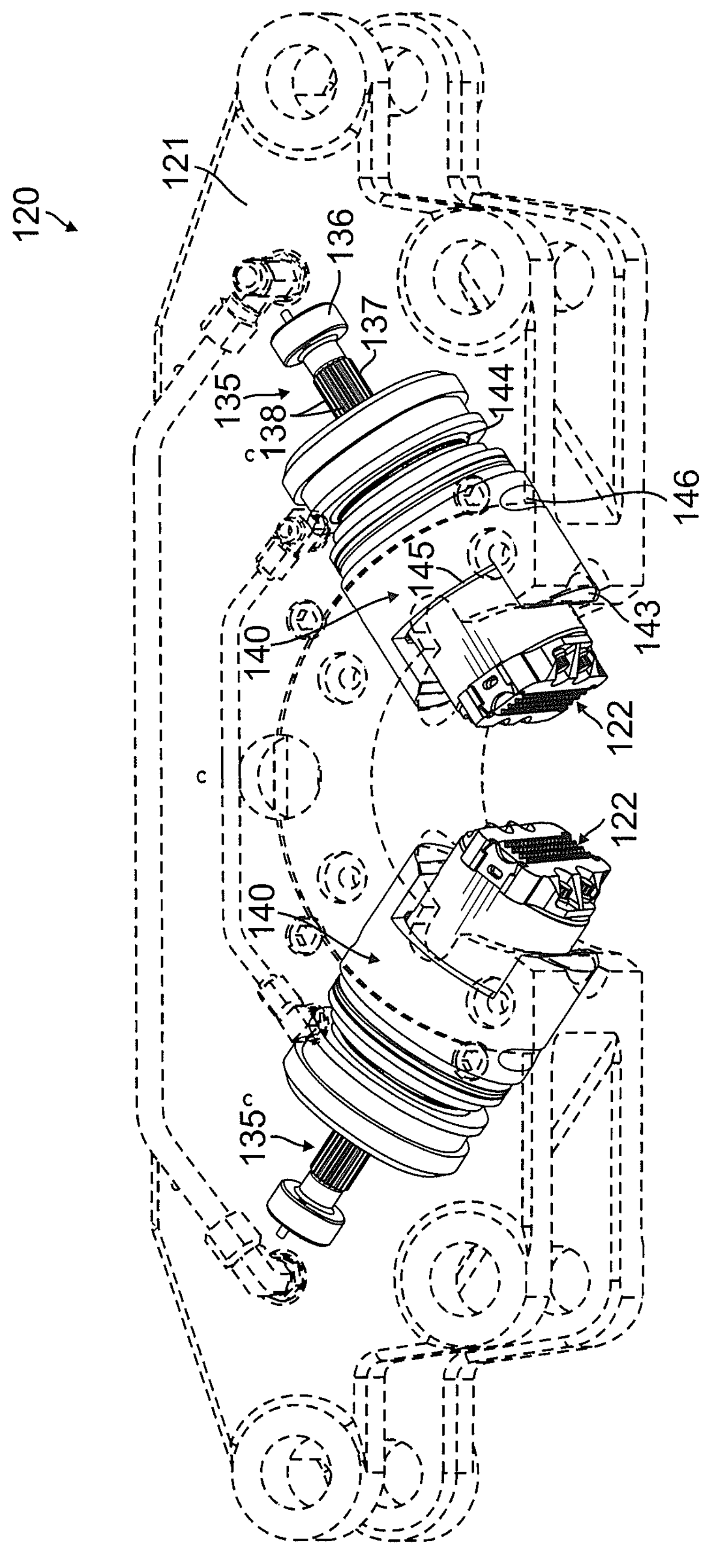

FIG. 2B

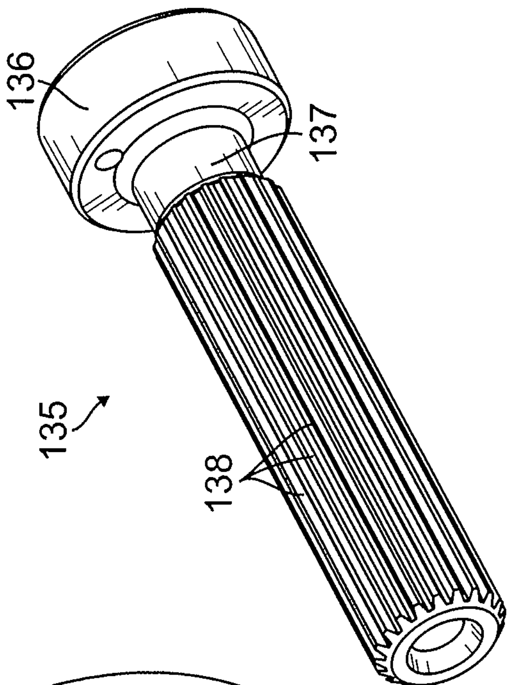

FIG. 2D

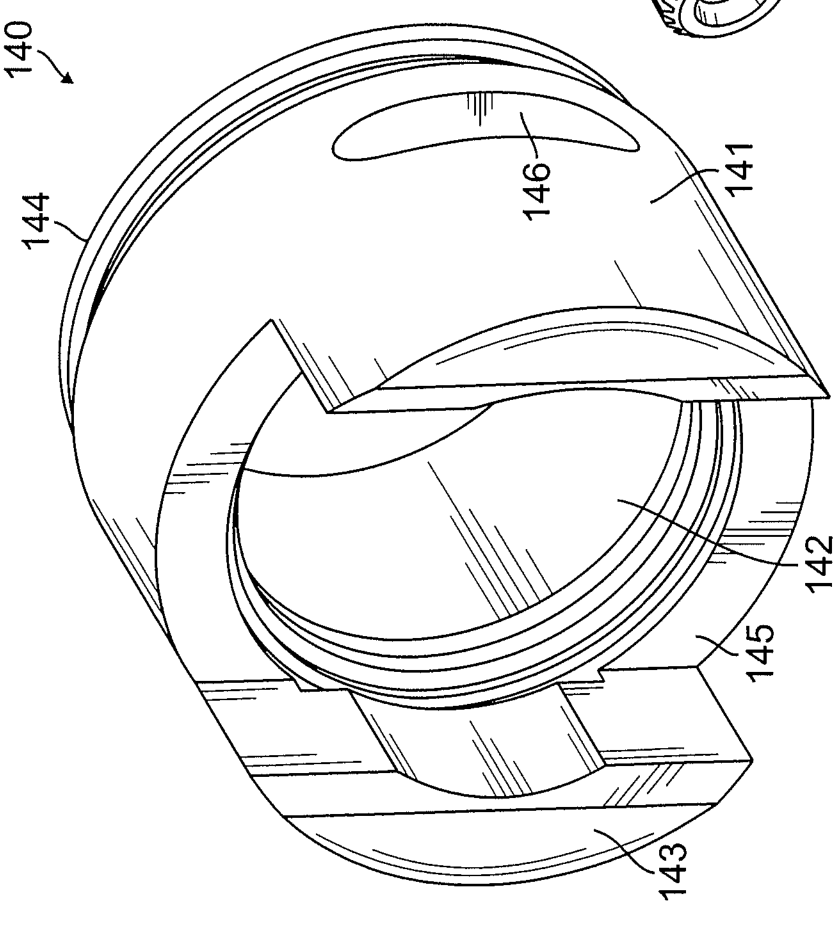

FIG. 2C

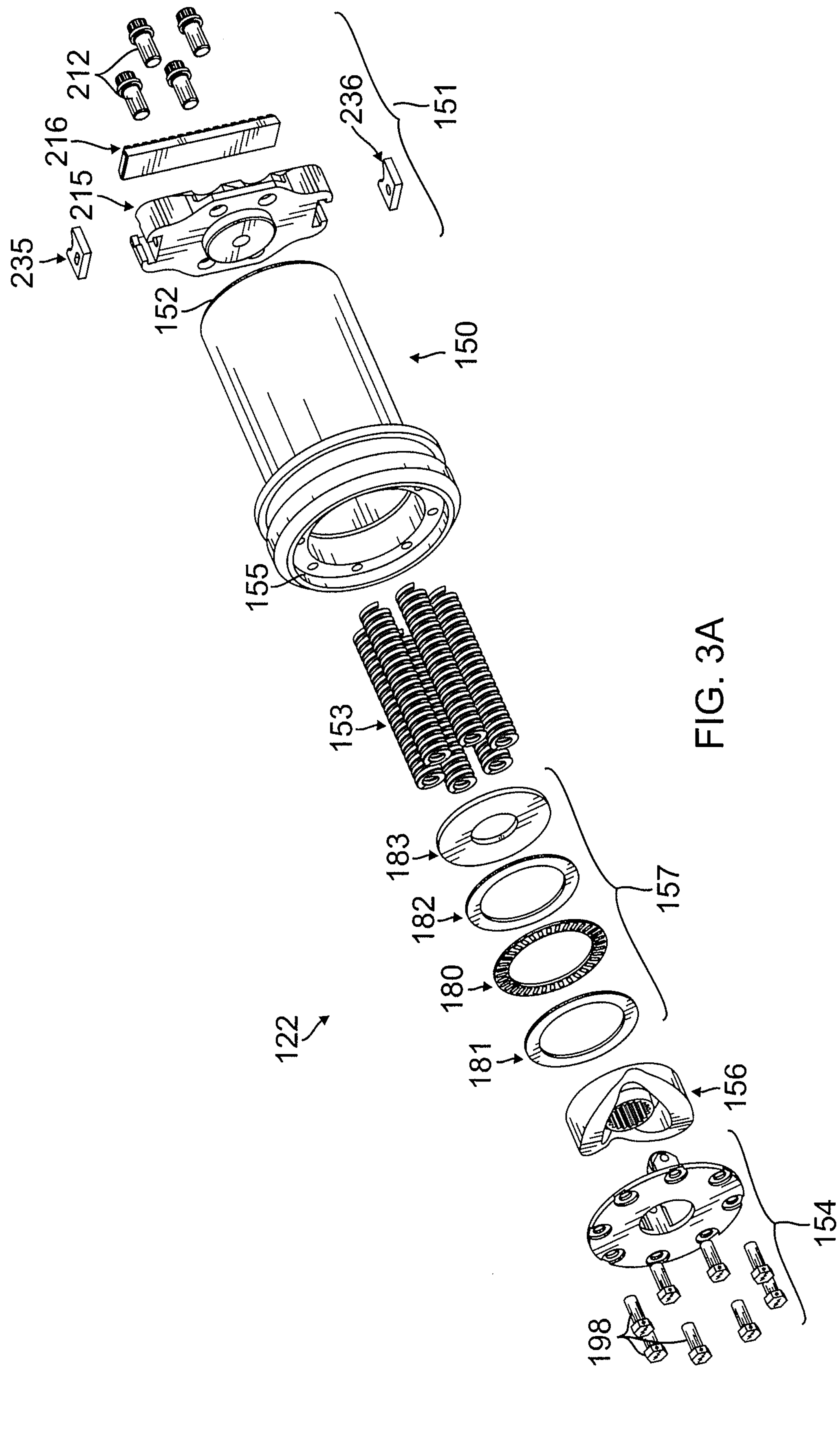
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FIG. 3A

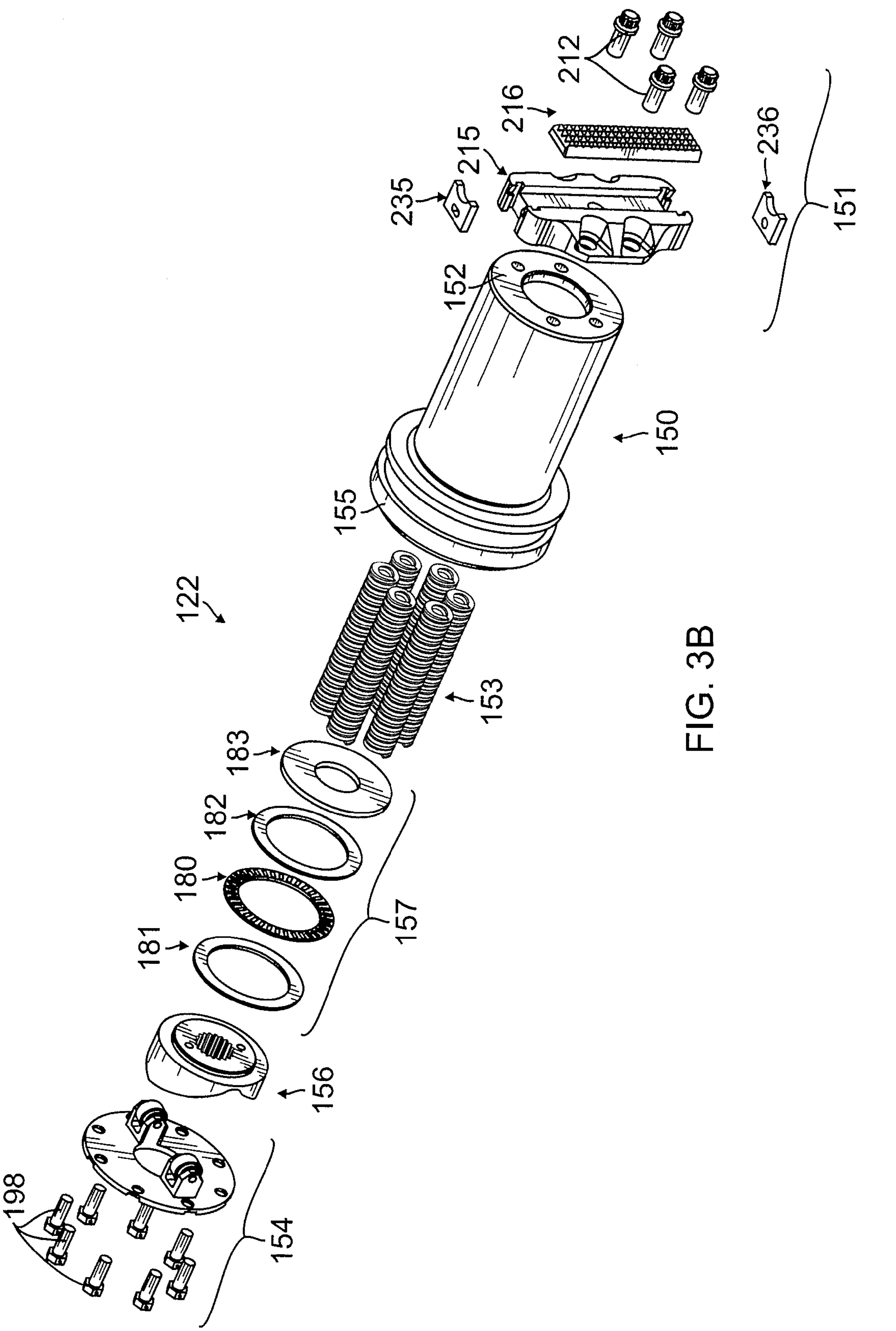
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FIG. 3B

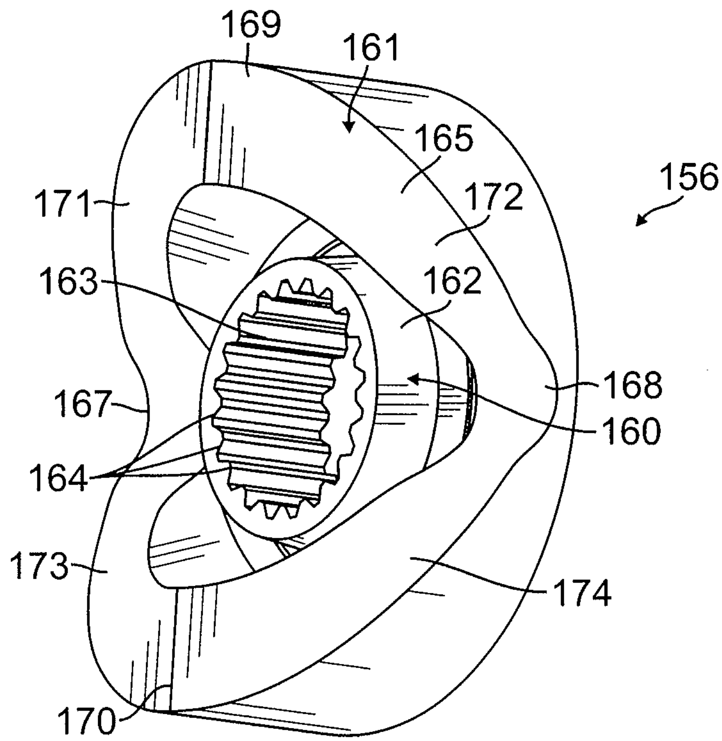
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FIG. 4A

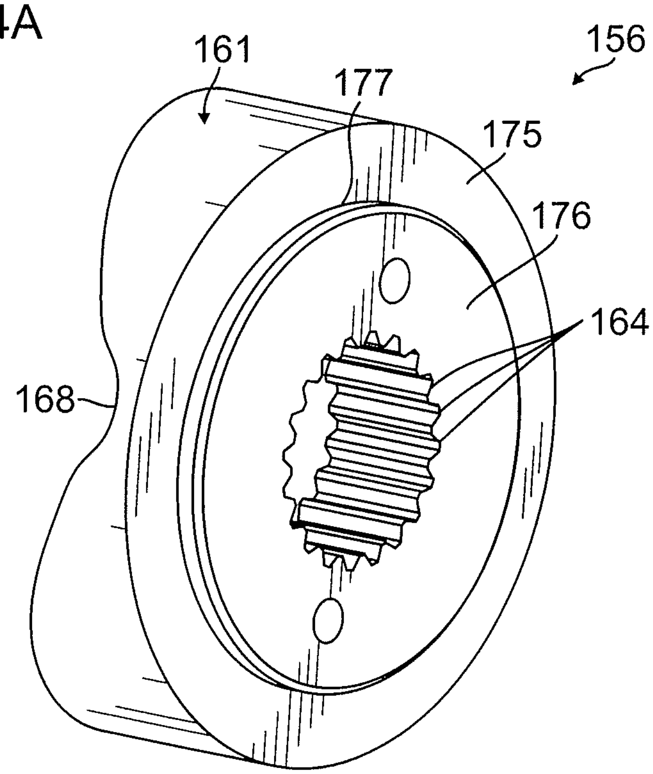
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FIG. 4B

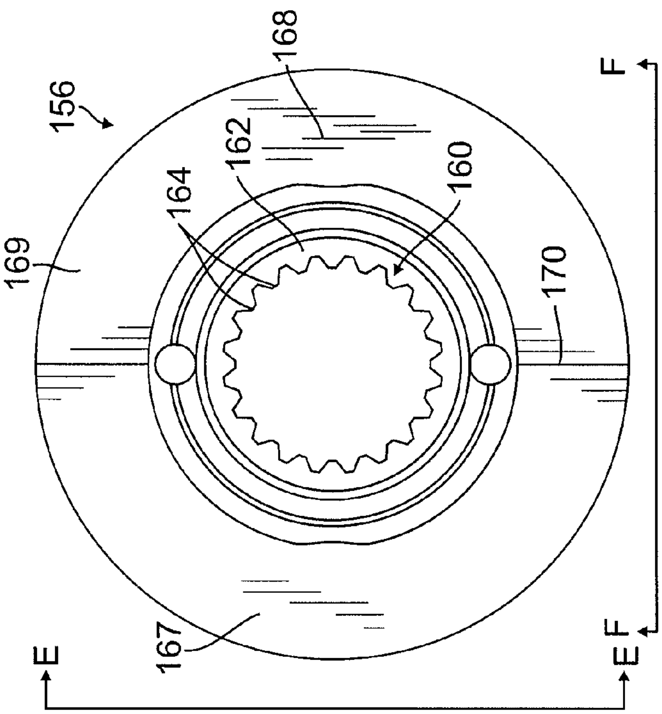

FIG. 4C

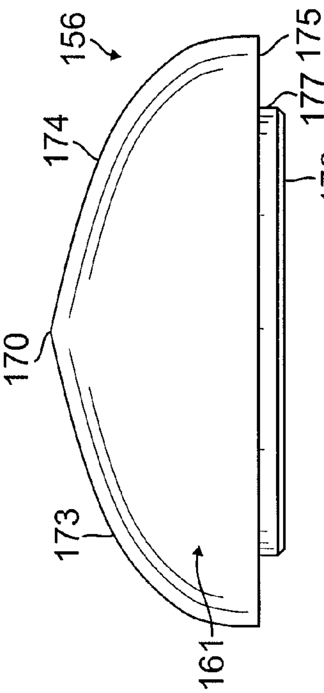

FIG. 4F

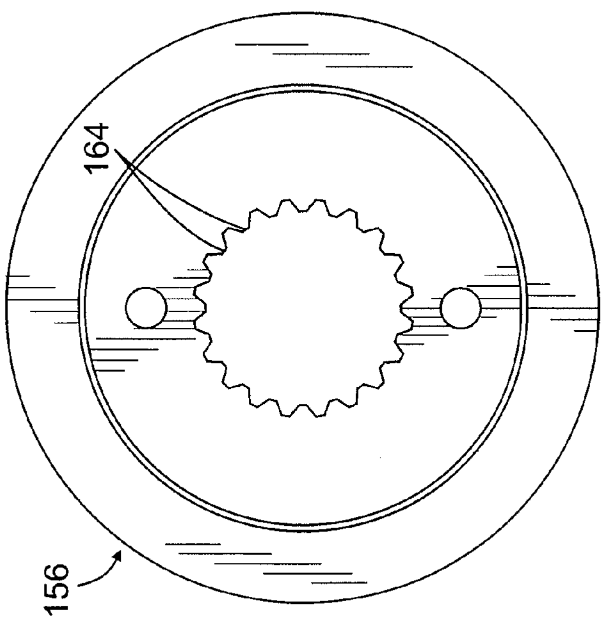

FIG. 4D

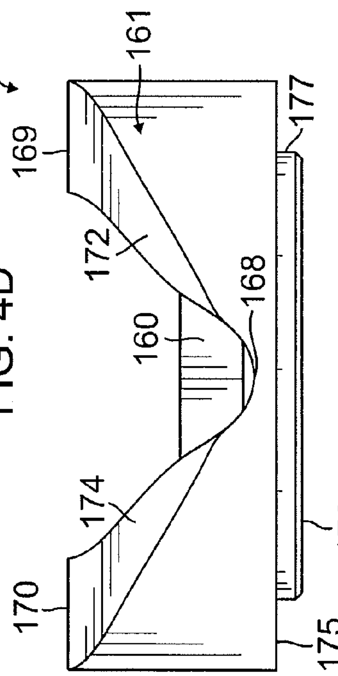

FIG. 4E

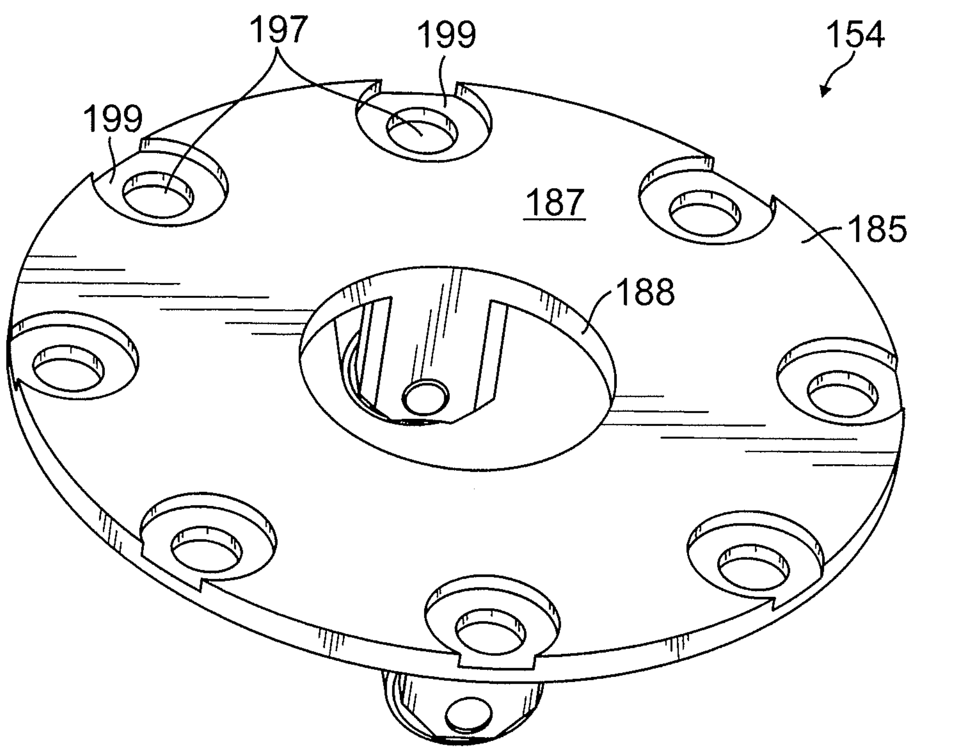
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FIG. 5A

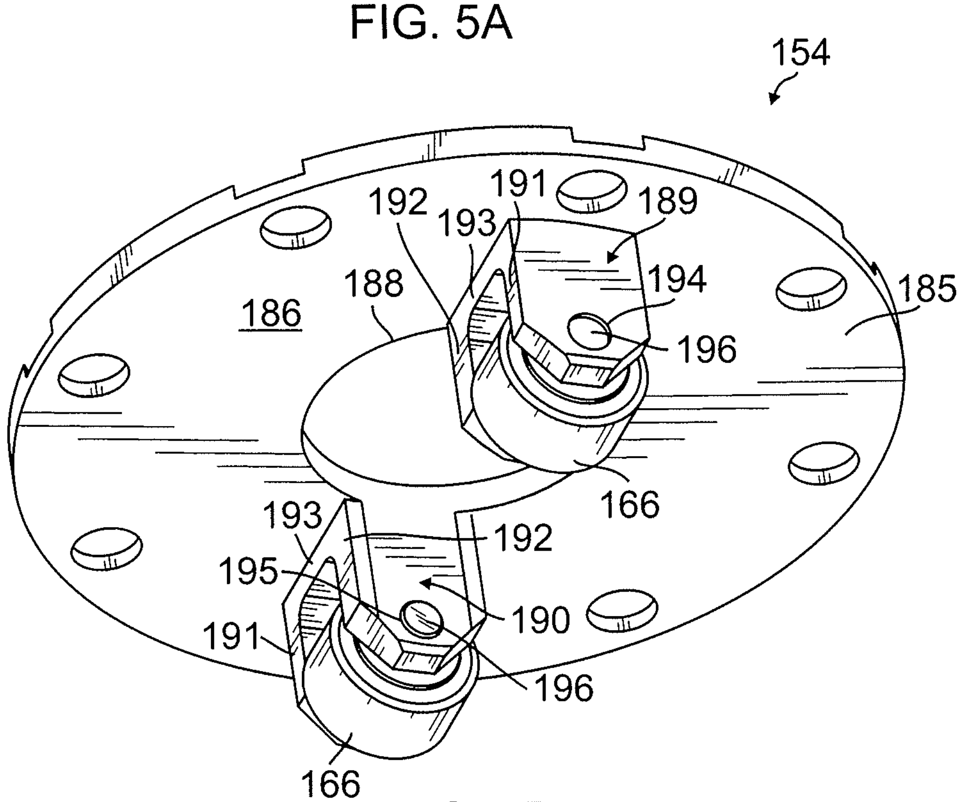
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FIG. 5B

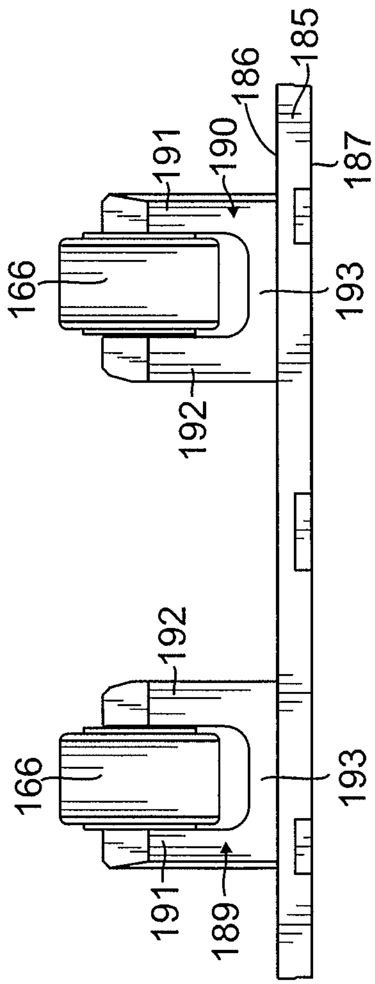

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FIG. 5C

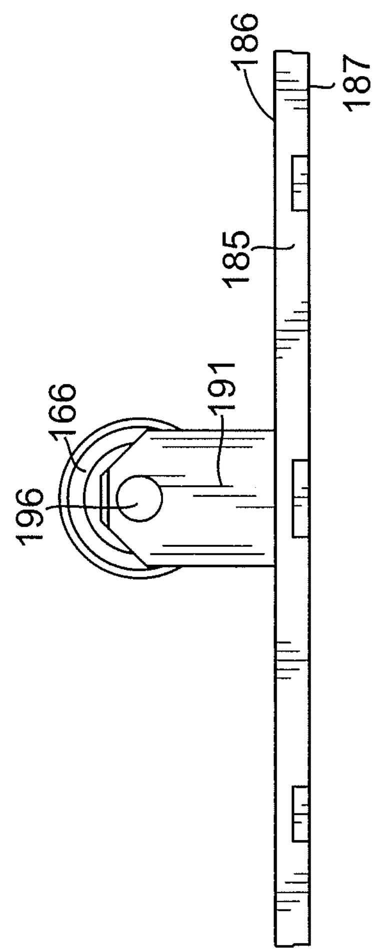

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FIG. 5D

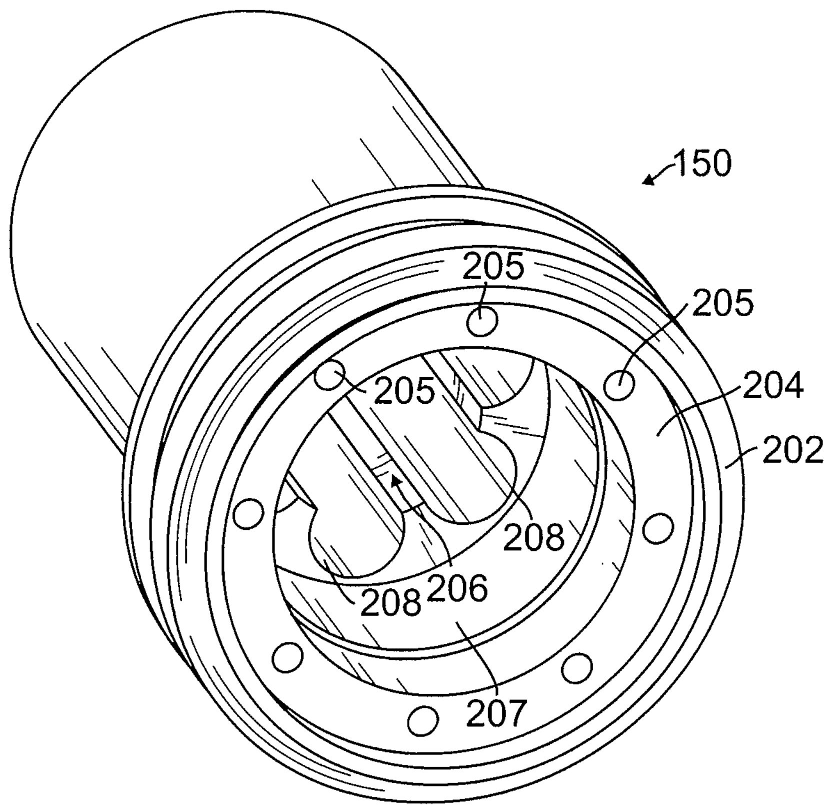
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FIG. 6A

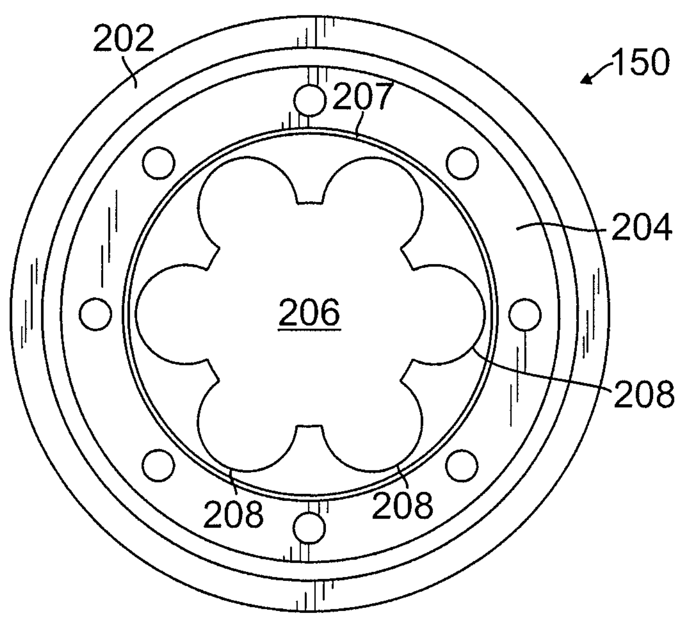
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FIG. 6C

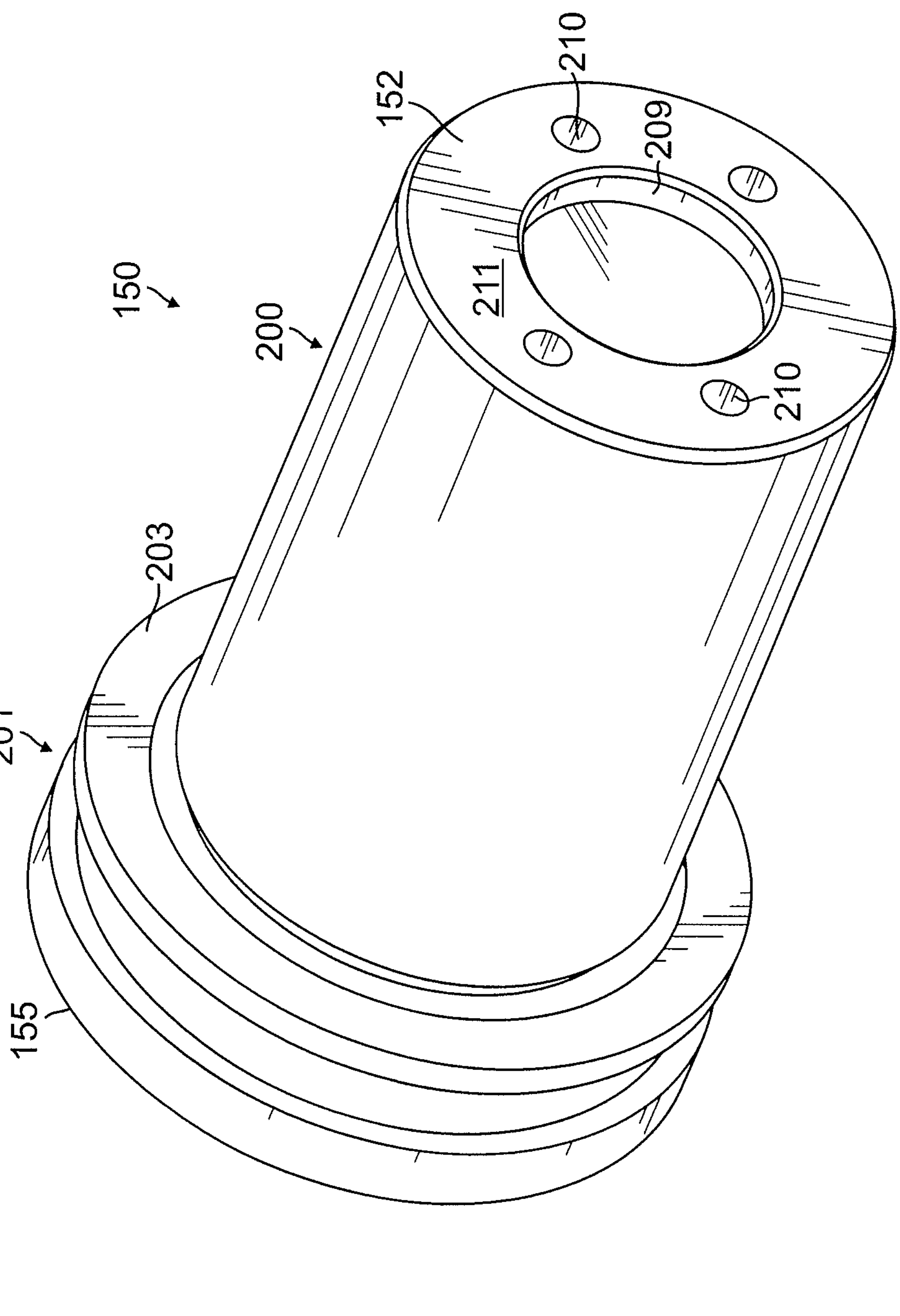

FIG. 6B

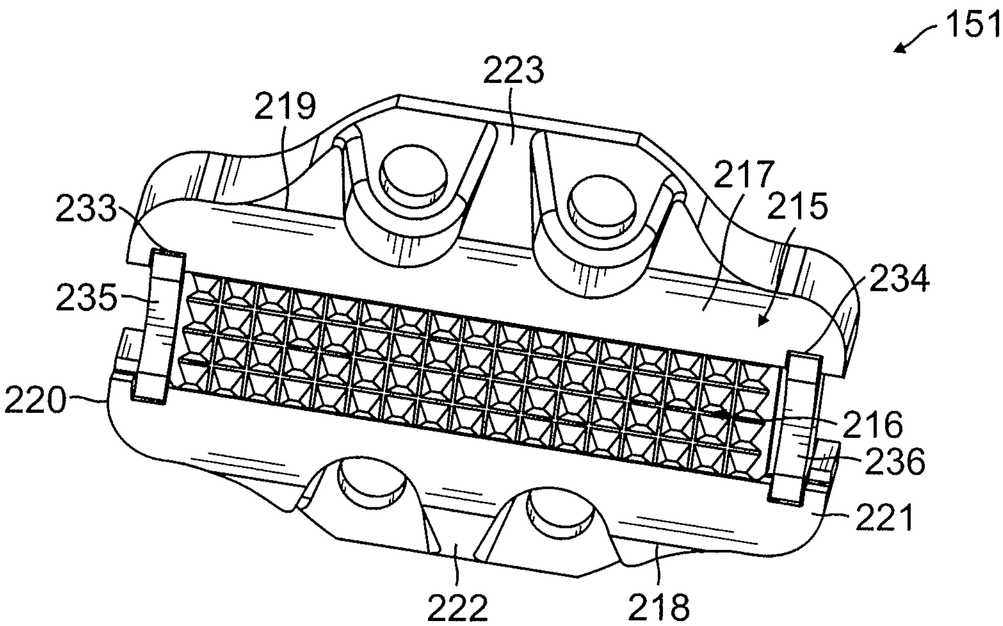
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FIG. 7A

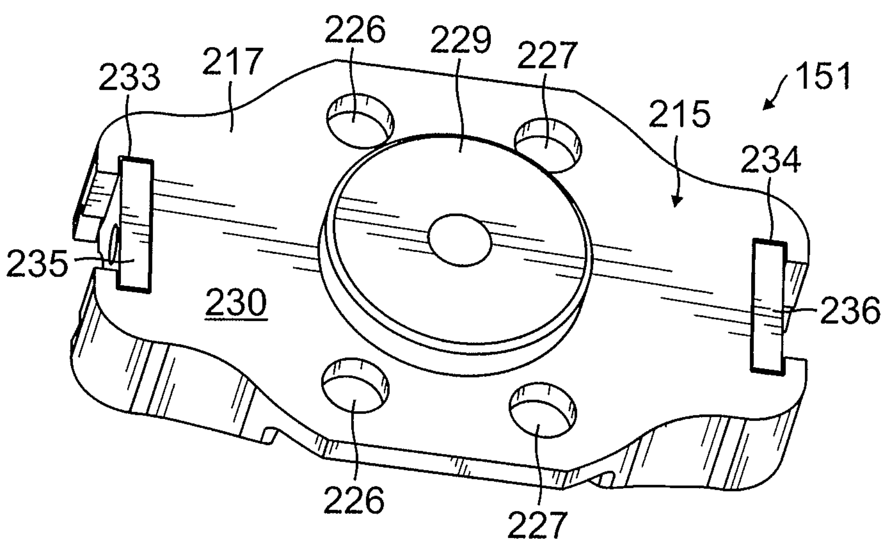
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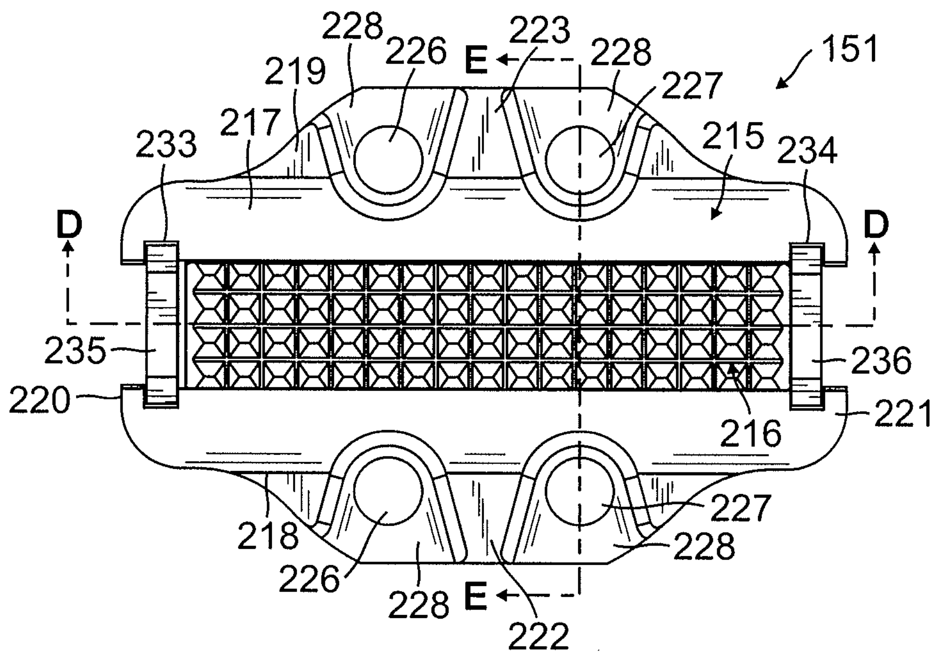
FIG. 7B



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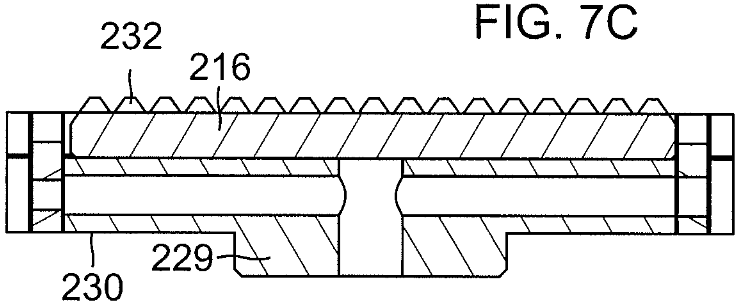

FIG. 7D

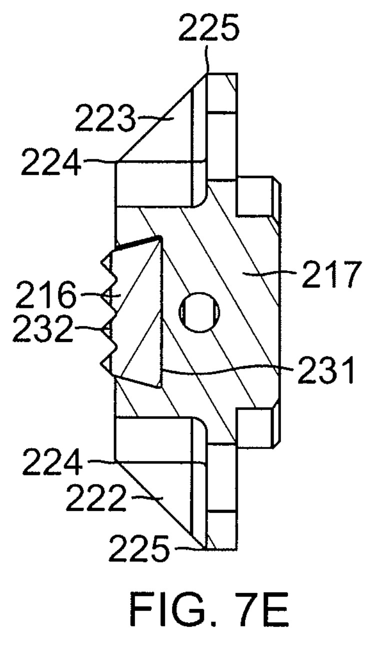

FIG. 7E

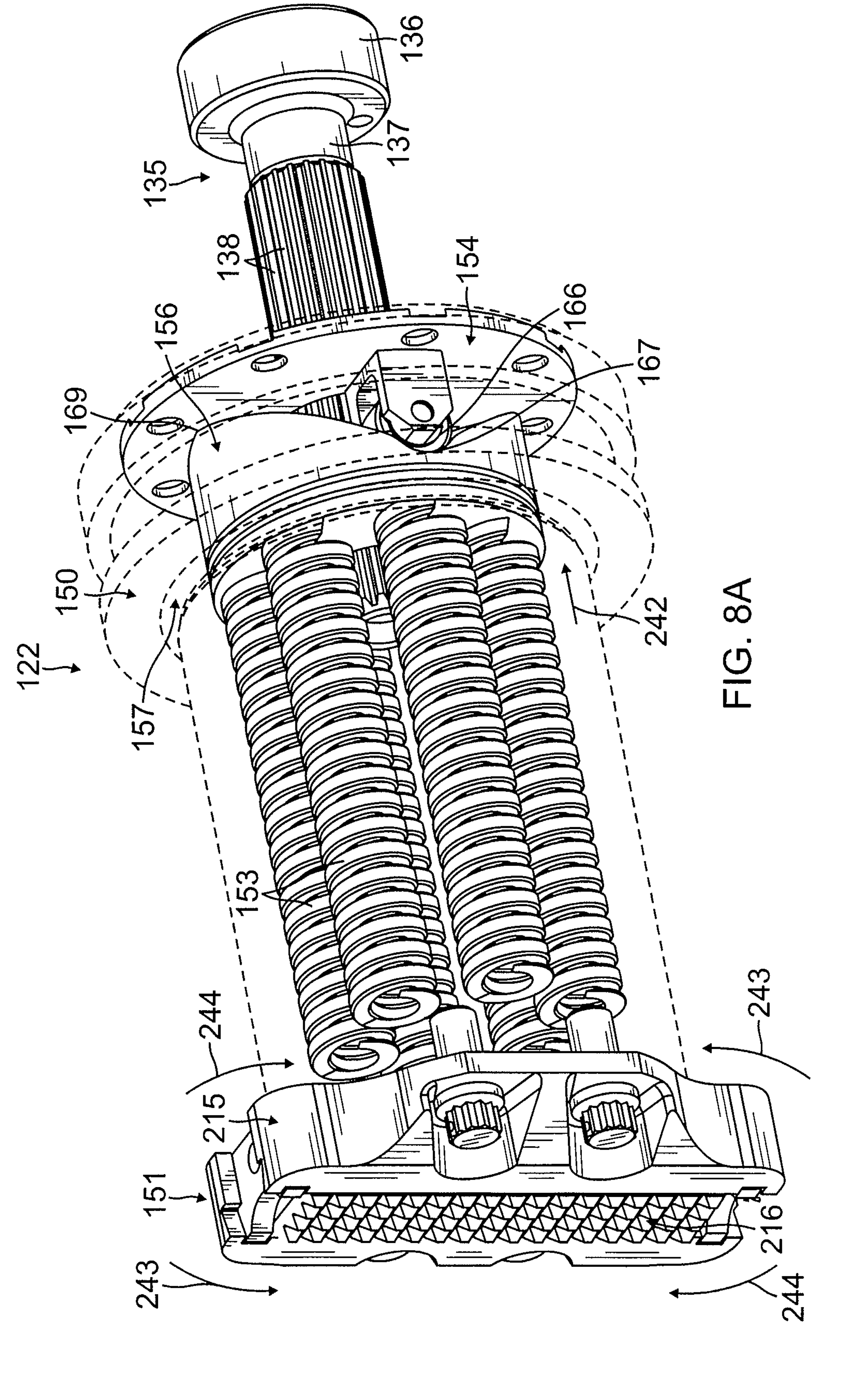
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FIG. 8A

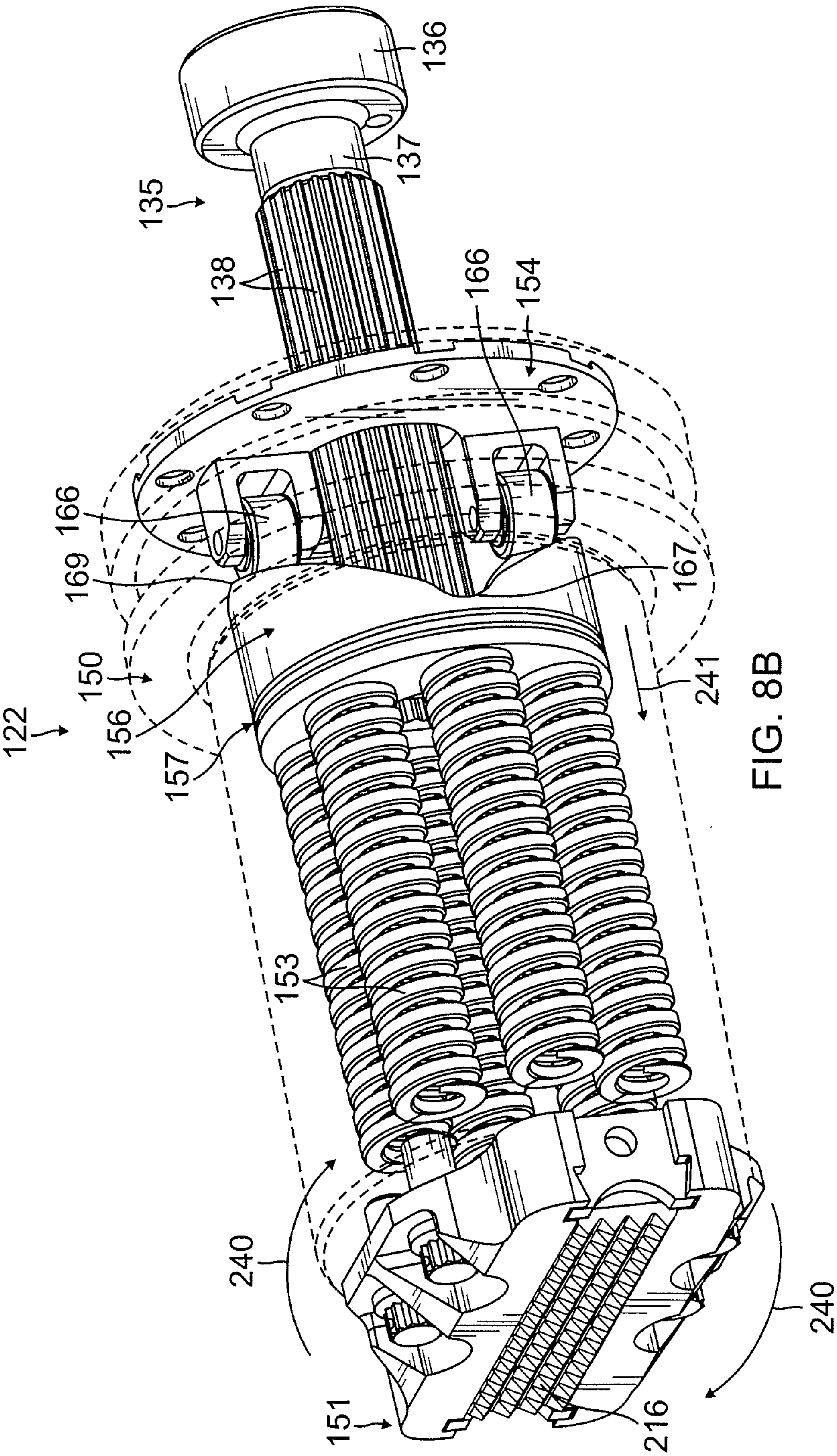
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FIG. 8B

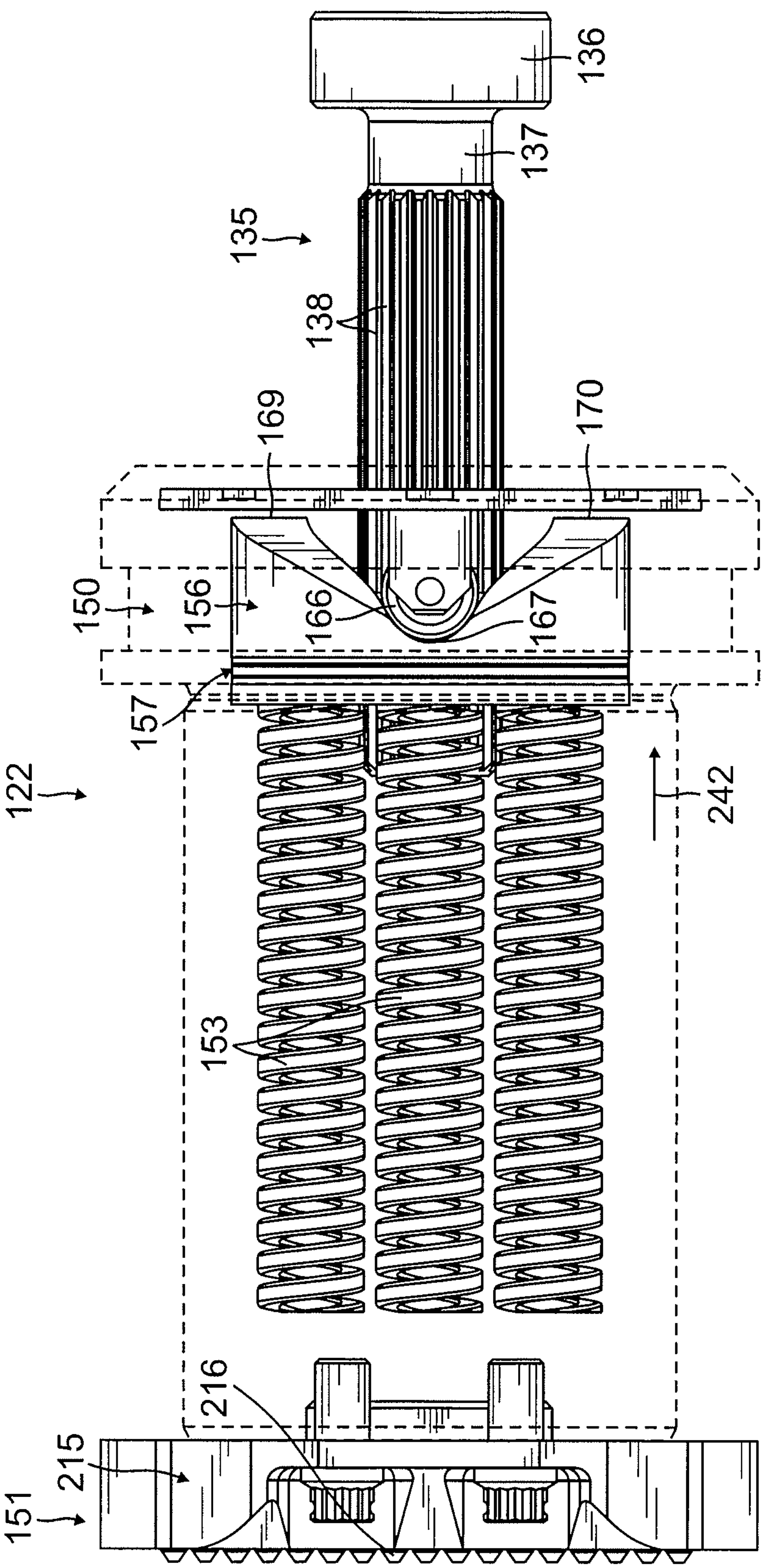
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FIG. 8C

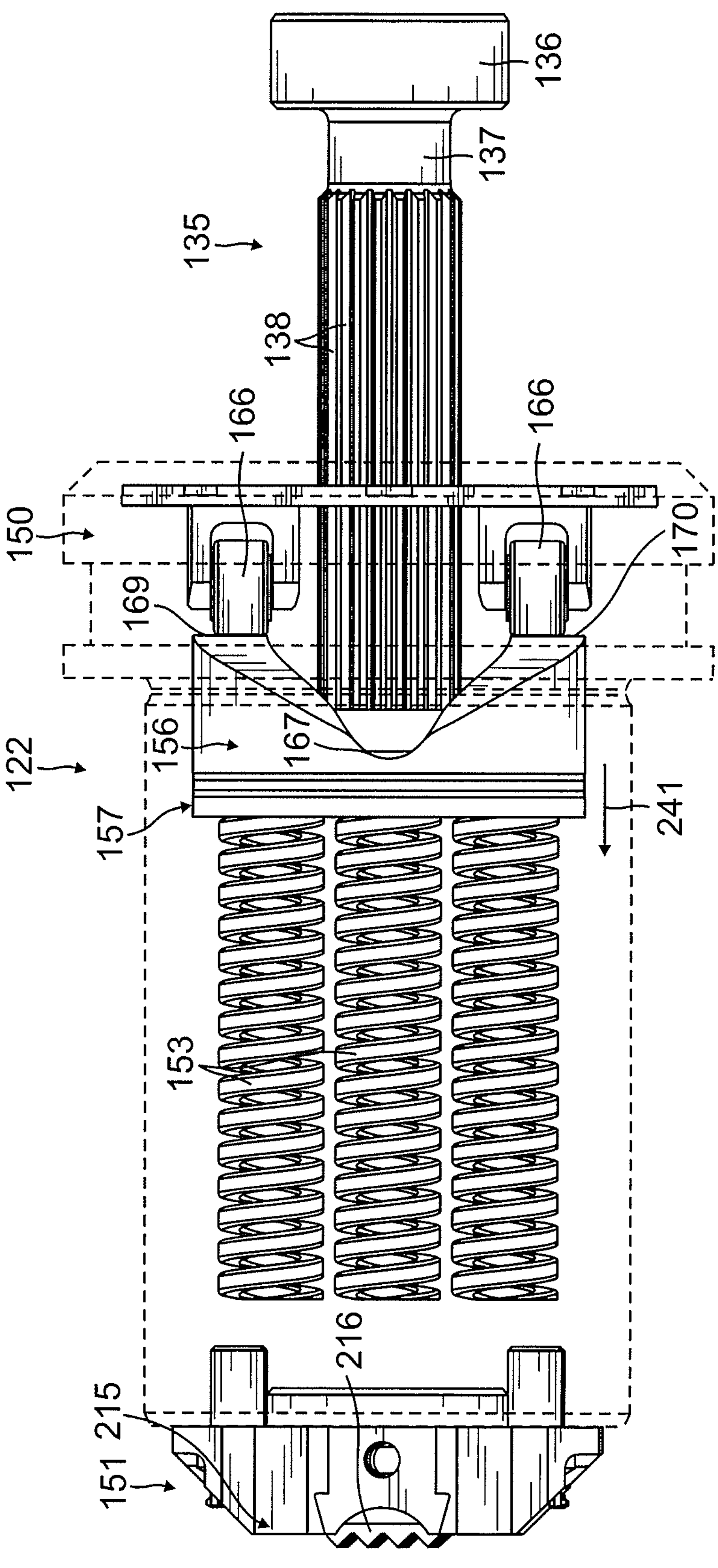
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FIG. 8D

SELF-ALIGNING PIPE GRIPPING ASSEMBLY AND METHOD OF MAKING AND USING THE SAME

FIELD

The present disclosure relates generally to pipe gripping assemblies, and more particularly to self-aligning pipe gripping pistons.

BACKGROUND

The process of drilling an oil well typically involves assembling drill strings and casing strings and inserting the drill strings and casing strings into the ground to form a well bore. The drill strings and casing strings extend downward from an oil drilling rig and into the ground. The drilling strings and the casing strings are rotationally driven into the ground by a top drive motor on the drilling rig. Drill strings typically include a series of drill segments that are threaded together. The lowest drill segment (i.e., the drill segment extending the furthest into the ground) includes a drill bit at its lower end. Typically, the casing string is provided around the drill string to line the well bore after the drilling operation has been completed. The casing string is configured to ensure the integrity of the well bore. The casing string includes a series of casing segments that are threaded together.

Recently, pipe gripping devices have been devised that utilize the existing top drive of the oil drilling rig to assemble the drill strings and the casing strings. Some conventional pipe gripping devices are fixedly mounted in a robust support. When such conventional gripping devices are subject to a large off-center force during operation, however, the conventional gripping device may become damaged, which is both costly and time consuming as the drilling operation must cease in order to repair the damaged pipe gripping device.

SUMMARY

The present disclosure is directed to various embodiments of a pipe gripping assembly and a self-aligning piston for use in oil well drilling systems. The pipe gripping assemblies and self-aligning pistons of the present disclosure are configured to selectively engage and disengage a pipe segment and to correct for misalignments relative to the pipe segment.

According to one embodiment of the present disclosure, the self-aligning piston includes a piston body configured to rotate between a first position and a second position, a resilient, energy-storing member coupled to the piston body, a roller assembly coupled to the piston body, and a cam disposed between the resilient, energy-storing member and the roller assembly. In one embodiment, the first position is an aligned orientation relative to the pipe segment and the second position is a misaligned orientation relative to the pipe segment. The resilient, energy-storing member is configured to bias the piston body into the first position (e.g., the aligned orientation) by rotating the roller assembly along the cam. In one embodiment, the resilient, energy-storing member includes several springs. In one embodiment, the self-aligning piston includes a die assembly coupled to the piston body. In one embodiment, the cam defines a contoured cam surface having a pair of opposing wells and a pair of opposing apices. Rollers on the roller assembly are configured to rest in the wells when the piston body is in the first position (e.g., the aligned orientation) and to roll along the cam surface toward the apices as the piston body is rotated into the second position (e.g., the misaligned orientation). The resilient, energy-storing member is configured to bias the rollers into the wells to return the piston body to the first position (e.g., the aligned orientation). In one embodiment, the resilient, energy-storing member is in a pre-compressed state when the piston body is in the first position and the resilient, energy-storing member is compressed further to a higher potential energy state when the piston body is in the second position. This state of higher potential energy provides the driving force to return the piston body to the normal, aligned, first position. In one embodiment, the self-aligning piston is configured to slide along a splined shaft between an engaged position with the pipe segment and a disengaged position. In one embodiment, the cam includes a hub having a splined surface configured to engage the splined shaft to prevent the rotation of the cam about the splined shaft.

According to another embodiment of the present disclosure, the pipe gripping assembly includes first and second jaws configured to clamp together around a pipe segment, at least one splined shaft fixedly housed in each of the first and second jaws, and at least one self-aligning piston housed in each of the first and second jaws. The self-aligned pistons are configured to slide along the splined shaft between an engaged position and a disengaged position. In one embodiment, each of the at least one self-aligning pistons includes a piston body configured to rotate between a first position (e.g., an aligned orientation relative to the pipe segment) and a second position (e.g., a misaligned orientation relative to the pipe segment), at least one resilient, energy-storing member coupled to the piston body, a roller assembly coupled to the piston body, and a cam disposed between the at least one resilient, energy-storing member and the roller assembly. The resilient, energy-storing member is configured to bias the piston body into the first position by rotating the roller assembly along the cam.

In one embodiment, each of the first and second jaws includes an extension port configured to receive pressurized hydraulic fluid to actuate each of the at least one self-aligning piston into the engaged position and a retraction port configured to receive pressurized hydraulic fluid to actuate each of the at least one self-aligning piston into the disengaged position. In one embodiment, the pipe gripping assembly includes at least one gland fixedly housed in each of the first and second jaws. The glands are configured to create a fluid-tight seal around each of the at least one self-aligning piston.

This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of embodiments of the present disclosure will become more apparent by reference to the following detailed description when considered in conjunction with the following drawings. In the drawings, like reference numerals are used throughout the figures to reference like features and components. The figures are not necessarily drawn to scale.

FIG. **1** is a side elevational view of a drilling rig incorporating a pipe gripping assembly according to one embodiment of the present disclosure;

FIG. **2**A is a perspective view of a pipe gripping assembly including a jaw housing two self-aligning piston assemblies according to one embodiment of the present disclosure;

FIG. **2**B is a perspective view of the embodiment of the pipe gripping assembly illustrated in FIG. **2**A with the jaw shown in phantom;

FIGS. **2**C and **2**D are front perspective views of a gland and a splined shaft, respectively, according to one embodiment of the present disclosure;

FIGS. **3**A and **3**B are exploded rear and front perspective views, respectively, of one of the self-aligning piston assemblies illustrated in FIGS. **2**A and **2**B;

FIGS. **4**A and **4**B are rear and front perspective views, respectively, of a cam according to one embodiment of the present disclosure;

FIGS. **4**C and **4**D are rear and front plan views, respectively, of the cam illustrated in FIGS. **4**A and **4**B;

FIGS. **4**E and **4**F are a side view and a top view, respectively, of the cam illustrated in FIGS. **4**A-**4**D;

FIGS. **5**A and **5**B are rear and front perspective views, respectively, of a roller assembly according to one embodiment of the present disclosure;

FIGS. **5**C and **5**D are a top view and a side view, respectively, of the roller assembly illustrated in FIGS. **5**A and **5**B;

FIGS. **6**A and **6**B are rear and front perspective views, respectively, of a piston housing according to one embodiment of the present disclosure;

FIG. **6**C is an rear plan view of the piston housing illustrated in FIGS. **6**A and **6**B;

FIGS. **7**A and **7**B are front and rear perspective views, respectively, of a die assembly according to one embodiment of the present disclosure;

FIG. **7**C is a front plan view of the die assembly illustrated in FIGS. **7**A and **7**B;

FIGS. **7**D and **7**E are cross-sectional views of the die assembly illustrated in FIG. **7**C taken along lines D-D and E-E, respectively;

FIGS. **8**A and **8**B are perspective views of the self-aligning piston assembly according to one embodiment of the present disclosure shown in an aligned orientation and a misaligned orientation, respectively, relative to a pipe segment; and

FIGS. **8**C and **8**D are side views of the self-aligning piston assembly according to one embodiment of the present disclosure shown in an aligned orientation and a misaligned orientation, respectively, relative to a pipe segment.

DETAILED DESCRIPTION

The present disclosure is directed to pipe gripping assemblies and self-aligning piston assemblies for use in oil well drilling systems to connect and disconnect pipe segments to a pipe string extending downwardly into a well bore. As used herein, the term "pipe segment" refers to casing segments and/or drill segments, and the term "pipe string" refers to casing strings and/or drill strings. The self-aligning piston assemblies of the present disclosure are configured to engage a pipe segment such that an output shaft of an existing top drive may be threaded onto the pipe segment. (i.e., the self-aligning piston assemblies fix the pipe segment such that the output shaft of the top drive may rotate relative to the pipe segment to connect the output shaft to the pipe segment).

Additionally, in response to an off-center load, the self-aligning piston assemblies of the present disclosure are configured to rotate out of alignment with the pipe segment in order to mitigate stresses on the self-aligning piston assemblies (i.e., the self-aligning piston assemblies are configured to rotate out of alignment for survivability). However, such misalignment between the self-aligning piston assemblies and the pipe segment reduces the efficacy of the pipe gripping assemblies and poses a risk of damaging the pipe segment through mishandling. Accordingly, the self-aligning piston assemblies of the present disclosure are also configured to correct for the undesirable rotational misalignment between the self-aligning piston assemblies and the pipe segments without requiring manual realignment of the various components of the self-aligning piston assemblies. Thus, the self-aligning piston assemblies of the present disclosure are configured to permit rotation of the self-aligning piston assemblies out of alignment with the pipe segment to mitigate stresses on the self-aligning piston assemblies and to then automatically return the self-aligning piston assemblies to their aligned orientation relative to the pipe segment.

The pipe gripping assemblies and self-aligning piston assemblies of the present disclosure may be incorporated into any suitable existing pipe running tool. A suitable pipe running tool is described in U.S. Pat. No. 7,510,006, the entire contents of which are hereby incorporated by reference. A pipe running tool **100** designed for use in a well drilling rig **101** is illustrated in FIG. **1**. The well drilling rig **101** includes a frame assembly **102** and a top drive assembly **103**. The top drive assembly **103** includes a drive motor **104** and a top drive output shaft **105** extending downwardly from the drive motor **104**. The pipe running tool **100** includes a frame assembly **106**, a rotatable shaft **107**, and a pipe engagement assembly **108** coupled to the rotatable shaft **107**. The rotatable shaft **107** of the pipe running tool **100** is rotatably coupled to the top drive output shaft **105** such that when the top drive output shaft **105** is rotated by the top drive motor **104**, the rotatable shaft **107** of the pipe running tool **100** is synchronously rotated. The pipe engagement assembly **108** of the pipe running tool **100** includes a spider/elevator **109** configured to selectively engage a pipe segment **110** to enable the well drilling rig **101** to create a threaded connection between the top drive output shaft **105** and the pipe segment **110** and subsequently a threaded connection between the pipe segment **110** and a pipe string **111**.

In order to create a threaded connection between the pipe segment **110** and the pipe string **111**, the pipe segment **110** is first hoisted upwardly until the upper end of the pipe segment **110** extends through the spider/elevator **109**. The spider/elevator **109** is then actuated into an engaged position to positively engage the pipe segment **110**. The engagement between the spider/elevator **109** and the pipe segment **110** prevents relative rotation between the pipe segment **110** and the spider/elevator **109**. The top drive motor **104** is then actuated to rotate the top drive output shaft **105**, which in turn creates a threaded connection between the top drive output shaft **105** and the pipe segment **110** via the rotatable shaft **107**. Once the top drive output shaft **105** is coupled to the pipe segment **110**, the spider/elevator **109** may be actuated into a disengaged position to release the pipe segment **110** such that the pipe segment **110** may rotate synchronously with the rotation of the top drive output shaft **105**.

The top drive assembly **103** is then lowered relative to the rig frame **102** along a pair of guide rails **114** to drive a threaded lower end **115** of the pipe segment **110** into contact with a threaded upper end **116** of the pipe string **111**. As illustrated in FIG. **1**, the pipe string **111** extends down into the well bore through a flush-mounted spider **117** mounted in a central opening **112** in the drill floor **113**. During the process of coupling the pipe segment **110** to the pipe string **111**, the flush-mounted spider **117** is actuated to engage the pipe string **111** to prevent relative rotation of the pipe string **111** with respect to the flush-mounted spider **117**. The top drive motor **104** is then actuated to rotate the top drive output shaft **105**, which in turn rotates the rotatable shaft **107** of the pipe running tool **100** and the pipe segment **110**. The pipe segment **110** is thus rotated into threaded engagement with the pipe string **111**. It will be appreciated that the well drilling rig **101** and the pipe running tool **100** are also configured to decouple (i.e., breakout) the pipe segment **110** from the pipe string **111**. The pipe gripping assemblies and self-aligning piston assemblies of the present disclosure may be integrated into the spider/elevator **109** of the pipe running tool **100** or any other suitable structure.

With reference now to the embodiment illustrated in FIGS. **2**A and **2**B, the pipe gripping assembly **120** includes a pair of jaws **121**, **121'** configured to clamp together around the pipe segment **110**. In one embodiment, both jaws **121**, **121'** are similar or identical such that the reference number designations used for the constituent parts and/or features of one of the jaws **121** applies equally to the constituent parts and/or features of the other jaw **121'**. In the illustrated embodiment, each jaw **121**, **121'** houses two self-aligning piston assemblies **122** arranged in a v-shaped configuration (i.e., the self-aligning piston assemblies **122** are arranged radially in the jaws **121**, **121'**). Together, the self-aligning piston assemblies **122** in the pair of jaws **121**, **121'** are arranged in an x-shaped configuration (i.e., each self-aligning piston assembly **122** in one of the jaws **121** corresponds to a diametrically opposed self-aligning piston assembly **122** in the other jaw **121'**). It will be appreciated, however, that each jaw **121**, **121'** may house any other suitable number of self-aligning piston assemblies **122**, such as, for example, one to four, and still fall within the scope and spirit of the present disclosure. Additionally, the self-aligning piston assemblies **122** may be arranged in any other suitable configuration in the jaws **121**, **121'**, such as, for example, an inline configuration, and still fall within the scope and spirit of the present disclosure.

With continued reference to the embodiment illustrated in FIGS. **2**A and **2**B, each jaw **121**, **121'** includes a semi-annular notch **123** and two apertures **124**, **125** (e.g., smooth cylindrical blind bores) extending radially outward from the semi-annular notch **123**. When the jaws **121**, **121'** are clamped together around the pipe segment **110**, the semi-annular notches **123** define a circular opening through which the pipe segment **110** passes. As illustrated in FIGS. **2**A and **2**B, the apertures **124**, **125** are configured to house the two self-aligning piston assemblies **122**.

The self-aligning piston assemblies **122** are configured to be actuated between an engaged position and a disengaged position such that the pipe gripping assembly **120** may selectively engage and disengage the pipe segment **110**. When the self-aligning piston assemblies **122** are actuated into the engaged position, the self-aligning piston assemblies **122** protrude inward from the semi-annular notches **123** in the jaws **121**, **121'**. In contrast, when the self-aligning piston assemblies **122** are actuated into the disengaged position, the piston assemblies **122** are retracted into apertures **124**, **125** in the jaws **121**, **121'** such that the self-aligning piston assemblies **122** do not protrude inward beyond the semi-annular notches **123** in the jaws **121**, **121'**. The self-aligning piston assemblies **122** are illustrated in a retracted, disengaged position in FIG. **2**A and in an extended, engaged position in FIG. **2**B.

In the extended position, the self-aligning piston assemblies **122** are configured to positively engage the pipe segment **110** to prevent relative rotation between the pipe segment **110** and the pipe gripping assembly **120**. Accordingly, the top drive output shaft **105** may be threaded into engagement with the pipe segment **110** by actuating the top drive motor **104**. It will be appreciated that the positive engagement between the self-aligning piston assemblies **122** and the pipe segment **110** also enables the oil drilling rig **101** to decouple the pipe segment **110** from the top drive output shaft **105**. In the retracted position, the self-aligning piston assemblies **122** are disengaged from the pipe segment **110** in order to permit the pipe segment **110** to rotate synchronously with the top drive output shaft **105**. Accordingly, when the self-aligning piston assemblies **122** are disengaged from the pipe segment **110**, the top drive motor **104** may create a threaded connection between the pipe segment **110** and the pipe string **111** (i.e., the top drive motor **104** may be actuated to rotate the top drive output shaft **105**, which in turn threads the pipe segment **110** into engagement with the pipe string **111**, which is held in place by the flush-mounted spider **117** or other suitable structure).

The self-aligning piston assemblies **122** may be actuated between the engaged and disengaged positions by any suitable means, such as, for example, a pneumatic motor, an electric motor, a hydraulic motor, or any combination thereof. In the embodiment illustrated in FIGS. **2**A and **2**B, the self-aligning piston assemblies **122** are configured to be actuated by a hydraulic motor. Each jaw **121**, **121'** includes at least one extension port **126** and at least one retraction port **127**. In the illustrated embodiment, the number of extension ports **126** and the number of retraction ports **127** corresponds to the number of self-aligning piston assemblies **122** housed in each jaw **121**, **121'** (i.e., each jaw **121**, **121'** houses two self-aligning piston assemblies **122** and includes two extension ports **126**, **126'** and two retraction ports **127**, **127'**). Extension and retraction ports **126**, **127** are configured to actuate one of the self-aligning piston assemblies **122** between the engaged and disengaged positions, and extension and retraction ports **126**, **127'** are configured to actuate the other self-aligning piston assembly **122** between the engaged and disengaged positions. It will be appreciated, however, that the number of extension ports **126** and the number of retraction ports **127** may differ from the number of piston assemblies **122**. In one embodiment, for example, each jaw **121**, **121'** may house two self-aligning piston assemblies **122** and may have a single extension port **126** and a single retraction port **127**.

The extension ports **126**, **126'** are configured to be coupled to a hydraulic system delivering pressurized hydraulic fluid to actuate the self-aligning piston assemblies **122** into the engaged, extended position, as shown in FIG. **2**B. The retraction ports **127**, **127'** are configured to be coupled to a hydraulic system delivering pressurized hydraulic fluid to actuate the self-aligning piston assemblies **122** into the disengaged, retracted position, as shown in FIG. **2**A. In the illustrated embodiment, the pipe gripping assembly **100** includes a t-joint **128** coupled to one of the extension ports **126**, an elbow joint **129** coupled to the other extension port **126'**, and a hydraulic line **130** extending between the t-joint **128** and the elbow joint **129**. Pressurized hydraulic fluid is configured to flow into the t-joint **128** and the t-joint **128** is configured to split the flow of pressurized hydraulic fluid equally between the two extension ports **126**, **126'**. Similarly, in the illustrated embodiment, the pipe gripping **100** assembly includes a t-joint **131** coupled to one of the retraction ports **127**, an elbow joint **132** coupled to the other retraction port **127'**, and a hydraulic line **133** extending between the t-joint **131** and the elbow joint **132**. Pressurized hydraulic fluid is configured to flow into the t-joint **131** and the t-joint **131** is configured to split the flow of pressurized hydraulic fluid equally between the two retraction ports **127**, **127'**.

With continued reference to FIGS. **2**A and **2**B, each of the self-aligning piston assemblies **122** is configured to slide along a shaft **135** as the self-aligning piston assemblies **122** are actuated between the engaged position (FIG. **2**B) and the disengaged position (FIG. **2**A). The shafts **135** are fixedly housed in the apertures **124**, **125** in the jaw **121**, **121'**. In the illustrated embodiment of FIGS. **2**B and **2**D, each shaft **135** includes a cylindrical body portion **136** and an elongated cylindrical rod **137** projecting inward from the cylindrical body portion **136**. At least a portion of the elongated cylindrical rod **137** is splined (i.e., the shaft **135** includes a series of notches or grooves **138** extending lengthwise along the elongated cylindrical rod **137** and circumferentially disposed around the elongated cylindrical rod **137**). As described in further detail below, the splined shafts **135** are configured to restrict rotation of some of the components of the self-aligning piston assemblies **122** and permit rotation of some other components of the self-aligning piston assemblies **122** in order to self-align the piston assemblies **122** with the pipe segment **110**.

Still referring to FIG. **2**B, each of the self-aligning piston assemblies **122** is slidably received in a gland **140**. The glands **140** are configured to create a fluid-tight seal around the self-aligning piston assemblies **122** (e.g., the glands **140** are configured to prevent hydraulic fluid from leaking out of the pipe gripping assembly **120**). The glands **140** are fixedly housed in the apertures **124**, **125** in the jaws **121**, **121'**. In one embodiment, the glands **140** are press-fit or friction fit into the apertures **124**, **125** in the jaws **121**, **121'**. As illustrated in FIG. **2**C, each gland **140** includes a cylindrical outer surface **141** and a central opening **142** (e.g., a smooth cylindrical bore) extending between inner and outer ends **143**, **144**, respectively, of the gland **140**. The central openings **142** in the glands **140** are configured to slidable receive the self-aligning piston assemblies **122** (i.e., the self-aligning piston assemblies **122** slide in the central openings **142** of the glands **140** as the self-aligning piston assemblies **122** are actuated between the engaged and disengaged positions). Each gland **140** also includes a rectangular recess **145** extending outward from the inner end **143**. When the self-aligning piston assemblies **122** are in the retracted, disengaged position (see FIG. **2**A), die assemblies, described in detail below, are received in the rectangular recesses **145** in the glands **140**. When the self-aligning piston assemblies **122** are in the extended, engaged position (see FIG. **2**B), the die assemblies extend out of the rectangular recesses **145** and beyond the inner ends **143** of the glands **140**. In the illustrated embodiment, the outer cylindrical surface **141** of each gland **140** also includes a pair of opposing arcuate notches (only one notch **146** is visible in FIG. **2**C). When the glands **140** are received in the apertures **124**, **125** in the jaws **121**, **121'**, as illustrated in FIGS. **2**A and **2**B, pins **147** are configured to extend down through openings **148** in the jaws **121**, **121'** and into the arcuate notches **146** to fixedly attach the glands **140** to the jaws **121**, **121'**.

With reference now to the embodiment illustrated in FIGS. **3**A and **3**B, each self-aligning piston assembly **122** includes a piston body **150**, a die assembly **151** configured to be coupled to an inner end **152** of the piston body **150**, a plurality of springs **153** configured to be housed in the piston body **150**, a roller assembly **154** configured to be coupled to an outer end **155** of the piston body **150**, a cam **156** disposed between the springs **153** and the roller assembly **154**, and a thrust bearing assembly **157** disposed between the cam **156** and the springs **153**.

With reference now to the embodiment illustrated in FIGS. **4**A-**4**F, the cam **156** includes a central hub **160** and a rim **161** surrounding the hub **160**. In the illustrated embodiment, the hub **160** is a thin-walled cylindrical protrusion having a smooth outer surface **162** and a splined inner surface **163** having a plurality of ridges or teeth **164** (i.e., the cam **156** includes a plurality of ridges or teeth **164** extending lengthwise along the inner surface **163** of the hub **160** and circumferentially disposed around the inner surface **163** of the hub **160**). The splined inner surface **163** of the hub **160** is configured to engage the splined shaft **135** (i.e., the teeth **164** on the cam **156** are configured to mesh with the grooves **138** in the splined shaft **135**). The engagement between the teeth **164** on the cam **156** and the grooves **138** in the shaft **135** is configured to prevent the cam **156** from rotating around the shaft **135** but permit the cam **156** to slide axially along the shaft **135**, the significance of which is described below (i.e., the splined cam **156** remains rotationally fixed relative to the splined shaft **135**, but is configured to be translated axially along the splined shaft **135**).

With continued reference to FIGS. **4**A-**4**F, the rim **161** of the cam **156** defines a pathway or cam surface **165** along which rollers **166** on the roller assembly **154** are configured to roll as the die assembly **151** on the self-aligning piston assembly **122** is rotating into and out of alignment with the pipe segment **110**. In the illustrated embodiment, the cam surface **165** includes opposing first and second recesses or wells **167**, **168** and opposing first and second peaks or apices **169**, **170** (i.e., the first and second wells **167**, **168** are diametrically opposed from each other on the rim **161**, and the first and second apices **169**, **170** are diametrically opposed from each other on the rim **161**). Additionally, in the illustrated embodiment, the apices **169**, **170** in the cam surface **165** are radially spaced apart from the wells **167**, **168** by approximately 90 degrees. The cam surface **165** also includes four sloped surface segments **171**, **172**, **173**, **174** extending between adjacent wells **167**, **168** and apices **169**, **170**. As described in further detail below, the contoured cam surface **165** is configured to convert the rotary motion of the die assembly **151** (i.e., as the die assembly **151** on the self-aligning piston assembly **122** is rotating into and out of alignment with the pipe segment **110**) into reciprocating linear motion of the cam **156** along the axis of the splined shaft **135**.

With continued reference to FIGS. **4**B, **4**C, **4**E, and **4**F, the cam **156** also includes an annular recess **175** extending outward from an inner end **176** of the cam **156**. The annular recess **175** extends around the periphery of the rim **161**. The annular recess **175** also defines an annular lip **177**. The annular recess **175** is configured to receive the bearing assembly **157**. In the illustrated embodiment of FIGS. **2**A and **2**B, the thrust bearing assembly **157** includes a thrust bearing **180**, a thrust washer **181** disposed on an outer end of the thrust bearing **180**, and a pair of thrust washers **182**, **183** disposed on an inner end of the thrust bearing **180**. The thrust bearing **180** may be any suitable type of thrust bearing, such as, for example, a cylindrical roller thrust bearing or a thrust ball bearing. The annular lip **177** on the cam **156** is configured to support inner diameters of the thrust bearing **180** and two of the thrust washers **181**, **182** disposed on opposite sides of the thrust bearing **180**.

With reference now to the embodiment illustrated in FIGS. **5**A-**5**D, the roller plate assembly **154** includes a flat, circular plate **185** having an inner surface **186** and an outer surface **187** opposite the inner surface **186**, and a central opening **188**, such as a smooth circular through hole, extending between the inner and outer surfaces **186**, **187**. The central opening **188** in the roller plate assembly **154** is configured to receive the splined shaft **135** (i.e., the inner diameter of the central opening **188** in the circular plate **185** is larger than the outer diameter of the elongated cylindrical rod **137** on the splined shaft **135** such that the elongated cylindrical rod **137** may extend through the central opening **188**). The central opening **188** in the circular plate **185** is configured to allow the roller plate assembly **154** to both rotate around the splined shaft **135** and slide axially along the splined shaft **135**, the significance of which is described below.

With continued reference to FIGS. **5**A-**5**D, the roller plate assembly **154** also includes two devises **189**, **190** coupled to the inner surface **186** of the circular plate **185**. The devises **189**, **190** may be either integrally formed with the flat, circular plate **185** or separately formed and coupled to the flat, circular plate **185** by any suitable means, such as bonding, welding, mechanical fastening, or combinations thereof. Each clevis **189**, **190** includes two closely spaced legs **191**, **192** and a bar **193** interconnecting outer ends of the legs **191**, **192**. The legs **191**, **192** of each clevis **189**, **190** each also include an opening **194**, **195**, respectively. Together, the pair of openings **194**, **195** in each clevis **189**, **190** are configured to support an axle **196**. The axle **196** of each clevis **189**, **190** is configured to rotatably support a roller **166** (i.e., the rollers **166** are configured to rotate about the axles **196**). As illustrated in FIGS. **5**A and **5**B, the devises **189**, **190** are oriented radially around the flat, circular plate **185**. In the illustrated embodiment, the roller plate assembly **154** includes two rollers **166**, although the roller plate assembly **154** may include any other suitable number of rollers **166**, such as, for example, one to four rollers, and still fall within the scope and spirit of the present disclosure. As described in further detail below, the rollers **166** on the roller plate assembly **154** are configured to roll along the cam surface **165** of the cam **156** as the die assembly **151** is moved into and out of alignment with the pipe segment **110**.

The roller plate assembly **154** also includes a plurality of openings **197** circumferentially disposed around the flat, circular plate **185**. The circumferentially disposed openings **197** in the circular plate **185** are configured to receive a plurality of fasteners **198** coupling the roller plate assembly **154** to the piston body **150**, as illustrated in FIGS. **2**A and **2**B. In the illustrated embodiment, the roller plate assembly **154** also includes a plurality of depressions **199** surrounding the openings **197** and extending inward from the outer surface **187** of the flat, circular plate **185**. The plurality of depressions **199** are configured to recess at least a portion of the fasteners **198** coupling the roller plate assembly **154** to the piston body **150**.

With reference now to the embodiment illustrated in FIGS. **6**A-**6**C, the piston body includes **150** a smaller cylindrical portion **200** and a larger cylindrical portion **201**. In the illustrated embodiment, the larger cylindrical portion **201** is located at an outer end of the smaller cylindrical portion **200**. The larger cylindrical portion **201** includes an outer surface **202** and an inner surface **203** opposite the outer surface **202**. The piston body **150** also includes an annular recess **204** extending inward from the outer surface **202** of the larger cylindrical portion **201**. The annular recess **204** is configured to receive the circular plate **185** of the roller plate assembly **154** (i.e., the circular plate **185** is configured to be seated in the annular recess **204**). In one embodiment, when the self-aligning piston assembly **122** is assembled, the outer surface **187** of the circular plate **185** of the roller plate assembly **154** is flush with the outer surface **202** of the larger cylindrical portion **201** of the piston body **150**. In alternate embodiments, the outer surface **187** of the roller plate assembly **154** may be recessed in the annular recess **204** of the piston body **150** or may protrude outward from the outer surface **202** of the piston body **150**. The larger cylindrical portion **201** of the piston body **150** also includes a plurality of openings **205**, such as threaded blind bores, extending inward from the annular recess **204** and circumferentially disposed around the annular recess **204**. The threaded blind bores **205** are configured to receive the plurality of fasteners **198** securing the roller plate assembly **154** to the piston body **150**. Although in the illustrated embodiment the piston body **150** includes eight threaded blind bores **205**, the piston body **150** may have any other suitable number of threaded blind bores **205**, such as, for example, two to twelve. In an alternate embodiment, the openings **205** in the piston body **150** may be smooth blind bores and the fasteners **198** securing the roller plate assembly **154** to the piston body **150** may be self-tapping fasteners.

With continued reference to FIGS. **6**A-**6**C, the piston body **150** also includes a central axial recess **206** (e.g., a smooth, cylindrical blind bore) configured to receive the splined cylindrical rod portion **137** of the shaft **135**. The central axial recess **206** is sized such that the piston body **150** may slide along the cylindrical rod portion **137** of the shaft **135** as the self-aligning piston assemblies **122** are actuated between the engaged position (FIG. **2**B) and the disengaged position (FIG. **2**A). The depth of the central axial recess **206** in the piston body **150** defines the maximum stroke of the piston body **150** (i.e., the depth of the central axial recess **206** in the piston body **150** defines the extent to which the self-aligning piston assembly **122** can extend inward to engage the pipe segment **110**). The piston body **150** also includes a depression **207** (e.g., a smooth blind bore) extending inward from the annular recess **204** in the larger cylindrical portion **201**. In the illustrated embodiment, the depression **207** is larger than, and concentric with, the central axial recess **206** in the piston body **150**. The depression **207** is configured to house the cam **156** and is sized to enable the cam **156** to slide within the piston body **150** and along the splined cylindrical rod **137** of the shaft **135**, the significance of which is described below (i.e., the depth of the depression **207** in the piston body **150** is sized to enable the cam **156** to slide within the piston body **150**). The piston body **150** also includes a plurality of smaller arcuate notches **208** extending inward from the depression **207**. In the illustrated embodiment, the arcuate notches **208** are circumferentially equidistantly disposed around the central axial recess **206** in the piston body **150**, as illustrated in FIG. **6**C. The arcuate notches **208** are configured to house and retain the springs **153** in the piston body **150**. Although in the illustrated embodiment the piston body **150** includes six arcuate notches **208**, the piston body **150** may have any other suitable number of arcuate notches **208**, such as, for example, one to ten, depending upon the number of springs **153** housed in the piston body **150**.

As illustrated in FIG. **6**B, the piston body also includes a cylindrical recess **209** (e.g., a smooth blind bore) and a plurality of openings **210** disposed around the cylindrical recess **209**. The cylindrical recess **209** and the plurality of openings **210** extend outward from an inner surface **211** of the smaller cylindrical portion **200** of the piston body **150**. The cylindrical recess **209** is configured to receive a portion of the die assembly **151**, and the plurality of openings **210** are configured to receive a plurality of fasteners **212** coupling the die assembly **151** to the inner end **152** of the piston body **150**. The openings **210** may be either smooth blind bores or threaded blind bores, depending upon the type of fasteners (e.g., self-tapping fasteners) coupling the die assembly **151** to the piston body **150**.

With reference now to the embodiment illustrated in FIGS. **7A-7E**, the die assembly **151** includes a die carrier **215** and a die insert **216** configured to be supported by the die carrier **215**. The die assembly **151** is configured to be coupled to the inner end **152** of the piston body **150** and to engage the pipe segment **110** when the self-aligning piston assembly **122** is in the extended, engaged position (see FIG. **2B**). The die carrier **215** includes a generally rectangular body portion **217** having a pair of longer sides **218**, **219** extending in a longitudinal direction and a pair of narrower sides **220**, **221** extending in a transverse direction. The die carrier **215** also includes a pair of feet **222**, **223** extending outward from the longer sides **218**, **219**, respectively, of the rectangular body portion **217**. Each of the feet **222**, **223** taper between a thicker, interconnected portion **224** coupled to the body portion **217** and a relatively thinner, free portion **225** opposite the thicker portion **224**. In the illustrated embodiment, each of the feet **222**, **223** also includes two openings **226**, **227** configured to receive the fasteners **212** coupling the die carrier **215** to the inner end **152** of the piston body **150** (i.e., the fasteners **212** coupling the die assembly **151** to the piston body **150** extend through the openings **226**, **227** in the die carrier **215** and into the openings **210** in the inner end **152** of the piston body **150**). In the illustrated embodiment, the die carrier **215** also includes a spotface **228** around each of the openings **226**, **227** such that the fasteners **212** coupling the die carrier assembly **151** to the piston body **150** rest flush against the die carrier **215**. The die carrier **215** also includes a cylindrical protrusion **229** extending outward from an outer surface **230** of the rectangular body portion **217**. The cylindrical protrusion **229** is configured to be received in the cylindrical recess **209** in the inner end **152** of the piston body **150**.

As best illustrated in FIG. **7E**, the die carrier **215** also includes a narrow, rectangular channel **231** extending in a longitudinal direction between the narrower sides **220**, **221** of the rectangular body portion **217**. The narrow channel **231** is configured to slidably receive the die insert **216**. In the illustrated embodiment, the die insert **216** is a generally rectangular plate having a friction-inducing inner surface **232**, such as, for example, a knurled surface, ridges, etching, striations, a coating, or any combinations thereof. The friction-inducing inner surface **232** of the insert **216** is configured to engage the pipe segment **110** when the self-aligning piston assembly **122** is in the extended, engaged position (FIG. **2B**). The die carrier **215** also includes a pair of notches **233**, **234** in the narrower sides **220**, **221**, respectively, of the rectangular body portion **217**. The notches **233**, **234** are configured to receive end caps **235**, **236**, respectively, configured to retain the die insert **216** in the narrow channel **231** in the die carrier **215**.

With reference now to FIGS. **8A-8D**, the operation of the self-aligning piston assemblies **122** will now be described. Under normal operating conditions, the die assemblies **151** are configured to be oriented vertically (i.e., lengthwise) along the pipe segment **110**. Additionally, under normal operating conditions, the rollers **166** on the roller plate assembly **154** are initially seated in the wells **167**, **168** of the cam **156**, as illustrated in FIGS. **8A** and **8C**. Accordingly, the positioning of the wells **167**, **168** in the cam **156** defines the initial orientation of the die assembly **151** relative to the pipe segment **110**. If, however, the die assemblies **151** are rotated (arrow **240** in FIG. **8B**) out of alignment with the pipe segment **110** during operation (e.g., due to an off-center load), the rollers **166** are rolled along the cam surface **165** towards the apices **169**, **170**, as illustrated in FIGS. **8B** and **8D** (i.e., if the die assemblies **151** are rotated (arrow **240**) out of the vertical, aligned orientation relative to the pipe segment **110**, the rollers **166** are rolled out of the wells **167**, **168** and towards the apices **169**, **170** on the cam **156**).

As the rollers **166** are rotated towards the apices **169**, **170** on the cam **156**, the cam **156** is translated inward (arrow **241** in FIG. **8B**) along the splined elongated rod **137** of the shaft **135**, thereby compressing the springs **153** housed in the piston body **150** (i.e., because the roller plate assembly **154** is fixedly attached to the piston body **150**, as the rollers **166** roll up along the sloped segments of the cam surface **165** toward the apices **169**, **170** on the cam **156**, the cam **156** is forced inward (arrow **241**) along the shaft **135** toward the die assembly **151**). In one embodiment, the springs **153** are initially in a pre-compressed state and are further compressed into a higher potential energy state as the rollers **166** are rotated towards the apices **169**, **170** on the cam **156** and the cam **156** is forced inward (arrow **241**) along the shaft **135**. The higher potential energy stored in the compressed springs **153** tends to force the rollers **166** to roll back down along the sloped segments of the cam surface **165** and into the wells **167**, **168** in the cam **156** (i.e., the force supplied by the compressed springs **153** tends to bias the rollers **166** on the roller plate assembly **154** down into the wells **167**, **168** in the cam **156**). As the rollers **166** are rolled back into the wells **167**, **168** in the cam **156**, the cam **156** is translated outward (arrow **242** in FIG. **8A**) along the splined elongated rod **137** of the shaft **135** and into its initial position, thereby reducing the compression in the springs **153** (i.e., the springs **153** are returned to their initial state of pre-compression). Accordingly, the springs **153** force the rollers **166** on the roller plate assembly **154** to roll back down into the wells **167**, **168** in the cam **156** such that the die assembly **151** returns to a vertically aligned position relative to the pipe segment **110**.

If the die assembly **151** is rotated (arrow **240** in FIG. **8B**) less than 90 degrees out of alignment with the pipe segment **110**, the rollers **166** will not reach the apices **169**, **170** on the cam **156**, which are radially spaced apart from the wells **167**, **168** in the cam **156** by approximately 90 degrees. Accordingly, if the die assembly **151** is rotated (arrow **240** in FIG. **8B**) less than 90 degrees, the rollers **166** and the cam **156** will operate to force the die assembly **151** to rotate (arrow **243** in FIG. **8A**) back into its initial, vertically aligned orientation relative to the pipe segment **110** (i.e., the rollers **166** will be forced back into the wells **167**, **168** in which they were initially seated).

If the die assembly **151** is rotated (arrow **240** in FIG. **8B**) between approximately 90 degrees and 270 degrees out alignment with the pipe segment **110**, the rollers **166** will roll past the apices **169**, **170** in the cam **156**. Accordingly, if the die assembly **151** is rotated (arrow **240**) between 90 degrees and 270 degrees, the rollers **166**, the springs **153**, and the cam **156** will operate to force the die assembly **151** to rotate (arrow **244** in FIG. **8A**) into a vertical orientation upside-down from its initial orientation (i.e., if the rotation of the die assembly **151** forces the rollers **166** to roll past the apices **169**, **170** on the cam **156**, the springs **153** will force the rollers **166** to roll down into the wells **167**, **168** in the cam **156** opposite from the wells **167**, **168** in which they were initially seated, but the die assembly **151** will return to an aligned, vertical orientation relative to the pipe segment **110**). Accordingly, the die assembly **151** returns to the aligned vertical orientation by rotating in a counterclockwise direction (arrow **243**) when the die assembly **151** is rotated (arrow **240** in FIG. **8**B) less than 90 degrees out of alignment with the pipe segment **110** and returns to the aligned vertical orientation by rotating in an clockwise direction (arrow **244**) when the die assembly **151** is rotated (arrow **240** in FIG. **8**B) between approximately 90 degrees and 270 degrees out alignment with the pipe segment **110**. Each incremental rotation of the die assembly **151** up to 180 degrees beyond 270 degrees will alternately force the die assembly **151** into its initial, vertical orientation relative to the pipe segment **110** and a vertical orientation upside-down from its initial orientation. Accordingly, regardless of the degree of rotation of die assembly **151** out of alignment with the pipe segment **110**, the die assembly **151** is configured to be automatically returned to an aligned (e.g., vertical) orientation relative to the pipe segment **110** by operation of the springs **153**, the cam **156**, and the rollers **166**. It will be appreciated that the die assembly **151** may be symmetric about a horizontal axis such that the die assembly **151** is configured to properly engage the pipe segment **110** when oriented either right-side-up or upside-down.

The piston body **150**, the die assembly **151**, the springs **153**, the roller assembly **154**, the cam **156**, and the thrust bearing assembly **157** may be made of any suitable materials, such as, for example, aluminum, steel, alloy, or carbon fiber reinforced plastic. The piston body **150**, the die assembly **151**, the springs **153**, the roller assembly **154**, the cam **156**, and the thrust bearing assembly **157** may be formed by any suitable process, such as, for example, extruding, machining, stamping, pressing, molding, welding, rapid prototyping using additive manufacturing techniques, or any combination thereof.

While this invention has been described in detail with particular references to exemplary embodiments thereof, the exemplary embodiments described herein are not intended to be exhaustive or to limit the scope of the invention to the exact forms disclosed. Persons skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described structures and methods of assembly and operation can be practiced without meaningfully departing from the principles, spirit, and scope of this invention, as set forth in the following claims. Although relative terms such as "outer," "inner," "upper," "lower," "below," "above," "vertical," "horizontal," and similar terms have been used herein to describe a spatial relationship of one element to another, it is understood that these terms are intended to encompass different orientations of the various elements and components of the invention in addition to the orientation depicted in the figures. Additionally, although the pipe gripping assemblies and self-aligning piston assemblies of the present invention have been described with reference to an oil drilling rig, it will be appreciated that the pipe gripping assemblies and self-aligning piston assemblies may be used in any other suitable application or industry.

What is claimed is:

1. A self-aligning piston configured to selectively engage and disengage a pipe segment, the self-aligning piston comprising:

a piston body configured to rotate between a first position and a second position;

at least one resilient, energy-storing member coupled to the piston body;

a roller assembly coupled to the piston body; and

a cam disposed between the at least one resilient, energy-storing member and the roller assembly,

wherein the resilient, energy-storing member is configured to bias the piston body into the first position by rotating the roller assembly along the cam.

2. The self-aligning piston of claim **1**, wherein the first position is a predetermined, aligned orientation relative to the pipe segment and the second position is a variable, misaligned orientation relative to the pipe segment.

3. The self-aligning piston of claim **1**, wherein the at least one resilient, energy-storing member comprises a plurality of springs.

4. The self-aligning piston of claim **1**, further comprising a splined shaft, wherein the self-aligning piston is configured to slide along the splined shaft between an engaged position with the pipe segment and a disengaged position.

5. The self-aligning piston of claim **4**, wherein the cam further comprises a hub having a splined surface configured to engage the splined shaft, the engagement between the hub and the shaft configured to prevent the rotation of the cam about the splined shaft.

6. The self-aligning piston of claim **1**, further comprising a die assembly coupled to the piston body.

7. The self-aligning piston of claim **1**, wherein:

the cam defines a contoured cam surface having a pair of opposing wells and a pair of opposing apices;

the roller assembly includes a plurality of rollers;

the rollers are configured to rest in the wells when the piston body is in the first position;

the rollers are configured to roll along the cam surface toward the apices as the piston body is rotated into the second position; and

the at least one resilient, energy-storing member is configured to bias the rollers into the wells to return the piston body to the first position.

8. The self-aligning piston of claim **1**, wherein the at least one resilient, energy-storing member is in a pre-compressed state when the piston body is in the first position, and the at least one resilient, energy-storing member is compressed further into a higher potential energy state when the piston body is in the second position.

9. A self-aligning piston assembly configured to selectively engage and disengage a pipe segment, the self-aligning piston assembly comprising:

a splined shaft; and

a piston assembly configured to slide along the splined shaft between an engaged position and a disengaged position, the piston assembly comprising:

a piston housing configured to rotate between an aligned position and a misaligned position relative to the pipe segment;

a die assembly coupled to an inner end of the piston housing;

a plurality of springs housed in the piston housing;

a cam defining a contoured cam surface having a pair of opposing wells and a pair of opposing apices; and

a roller assembly coupled to an outer end of the piston housing, the roller assembly including a plurality of rollers configured to roll along the cam surface,

wherein:

the rollers are configured to rest in the wells when the die assembly is in the aligned position;

the rollers are configured to roll along the cam surface toward the apices as the die assembly is rotated into the misaligned position; and

the springs are configured to bias the rollers into the wells to return the die assembly to the aligned position.

10. The self-aligning piston assembly of claim **9**, wherein the cam further comprises a hub having a splined surface configured to engage the splined shaft, the engagement between the hub and the shaft configured to prevent the rotation of the cam about the splined shaft.

11. The self-aligning piston assembly of claim **9**, wherein the die assembly comprises:

a die holder; and

a die insert configured to be supported by the die holder.

12. The self-aligning piston assembly of claim **9**, wherein the piston housing comprises a plurality of smooth blind bores configured to receive the plurality of springs.

13. The self-aligning piston assembly of claim **9**, further comprising a thrust bearing disposed between the cam and the plurality of springs.

14. A pipe gripping assembly configured to selectively engage and disengage a pipe segment, the pipe gripping assembly comprising:

first and second jaws configured to clamp together around the pipe segment;

at least one splined shaft fixedly housed in each of the first and second jaws; and

at least one self-aligning piston housed in each of the first and second jaws and configured to slide along the splined shaft between an engaged position and a disengaged position, each of the at least one self-aligning pistons comprising:

a piston body configured to rotate between a first position and a second position;

at least one resilient, energy-storing member coupled to the piston body;

a roller assembly coupled to the piston body; and

a cam disposed between the at least one resilient, energy-storing member and the roller assembly,

wherein the resilient, energy-storing member is configured to bias the piston body into the first position by rotating the roller assembly along the cam.

15. The pipe gripping assembly of claim **14**, wherein each of the first and second jaws further comprises:

an extension port configured to receive pressurized hydraulic fluid to actuate each of the at least one self-aligning piston into the engaged position; and

a retraction port configured to receive pressurized hydraulic fluid to actuate each of the at least one self-aligning piston into the disengaged position.

16. The pipe gripping assembly of claim **14**, further comprising at least one gland fixedly housed in each of the first and second jaws, the at least one gland configured to create a fluid-tight seal around each of the at least one self-aligning piston.

17. The pipe gripping assembly of claim **14**, wherein:

the cam defines a contoured cam surface having a pair of opposing wells and a pair of opposing apices;

the roller assembly includes a plurality of rollers;

the rollers are configured to rest in the wells when the piston body is in the first position;

the rollers are configured to roll along the cam surface toward the apices as the piston body is rotated into the second position; and

the at least one resilient, energy-storing member is configured to bias the rollers into the wells to return the piston body to the first position.

18. The pipe gripping assembly of claim **14**, wherein the cam further comprises a hub having a splined surface configured to engage the splined shaft, the engagement between the hub and the shaft configured to prevent the rotation of the cam about the splined shaft.

19. The pipe gripping assembly of claim **14**, further comprising a die assembly coupled to an inner end of the piston body.

20. The self-aligning piston of claim **14**, wherein the at least one resilient, energy-storing member is in a pre-compressed state when the piston body is in the first position, and the at least one resilient, energy-storing member is compressed further into a higher potential energy state when the piston body is in the second position.

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